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EDITORIAL

The present period is one of great importance, both to astronautics in general and to our own Society.

The International Geophysical Year has begun, and with it the most intensive programme of rocket exploration of the upper atmosphere yet undertaken. Later in this programme will come the launching of the American and Russian satellites. It was good to hear the announcement at the recent Joint Symposium held at Cranfield that preliminary work has started in Government departments on the design of a British satellite, and all members will join in the hope that the money will be forthcoming to translate this design into a working piece of hardware. Both in America and Russia, comparatively large rockets have now reached an advanced stage of development, and while the first test of Atlas was a relative failure this is no doubt merely a temporary set-back. Other missiles are breaking records—the Jupiter has reached a height of approximately 700 miles and the Lockheed X17 is reported to have attained a speed of 9,240 m.p.h. We welcome the technical progress that these achievements imply, at the same time as we hope that it will never prove necessary to use the missiles for the purpose for which they were constructed.

As regards the Society, a critical period in our stage of development has been reached. The Cranfield Symposium on High Altitude and Satellite Rockets was a great success (a report will appear shortly in *Spaceflight*), and we shall organize further conferences along these lines. We are receiving many useful contributions for the *Journal* and for *Spaceflight*, and it is desirable that we increase the frequency and size of these publications. The Council has under consideration other proposals for increasing the usefulness of the Society. But all these activities can only come about if there is a corresponding increase in the income of the Society—indeed in the present inflationary situation even to maintain our present activities an increased income is necessary. To obtain this, it may well prove essential to increase subscription rates, but meanwhile there are many ways in which members can help—by obtaining new members or subscriptions to the *Journal*, by encouraging their firms to advertise in our publications, by voluntary assistance, donations, etc.

THE SIMULATION OF GRAVITY*

By Derek F. Lawden,† M.A., Fellow

SUMMARY

The artificial gravitational field produced by rotating a spaceship or artificial satellite about its axis is compared and contrasted with normal gravity at the Earth's surface.

1. The Weightless State

Although there is no reason to expect that a man in the weightless state will experience any disadvantageous physiological effects, the absence of gravity over an extensive period may produce intolerable psychological stress due, perhaps, to a sustained attempt by the more primitive and unconscious elements of his mind to solve the insoluble problem—in which direction is the vertical? On the other hand, psychological adaptation to such unusual conditions may be attained after a few minutes and freedom from the load imposed by gravity may then be exhilarating. The relevant experimental data available today are derived from tests on animals which have been subjected to the weightless state in freely falling rockets, and tests upon human beings in aircraft guided along a parabolic path of free fall. The duration of any such tests cannot exceed a minute or so and it follows that no reliable conclusions can be drawn as to the effect upon man of days spent in the weightless state. The question will only be decided by launching a manned artificial satellite into an orbit about the Earth.

But even if it is eventually proved that man can adapt himself to the weightless state without difficulty, the absence of gravity may still be undesirable for a number of reasons. Dust will accumulate in the air instead of falling to the ground. Loose objects will drift about the compartment. Walking will be impossible without special shoes. Cups, bowls, etc., will no longer serve their purpose. Convective circulation of the air will cease, though this could easily be remedied by the use of fans and ducts. For these, and many other reasons, it will probably be deemed desirable to introduce a substitute for gravity. That this could be accomplished by the simple process of setting the spaceship into rotation about its axis was appreciated at a very early stage in astronautical development and modern designs for artificial satellites, such as that of Von Braun, are usually depicted as being in rotation for this reason. In this article we shall explain how this artificial gravitational field arises and shall draw attention to certain of its features which distinguish it from the gravitational field of our everyday experience.

2. Motion Relative to a Rotating Frame

In Fig. 1, O is a point on the axis of a spaceship or artificial satellite about which it is rotating with constant angular velocity ω. The plane of the figure is perpendicular to the axis. OX is an arbitrary line fixed in space and OR is a

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† Professor of Mathematics, Canterbury University College, Christchurch, New Zealand.

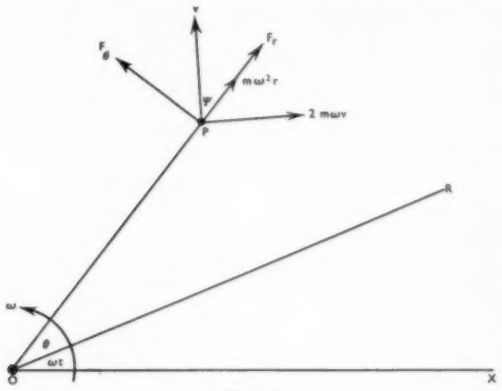

FIG. 1

line fixed in the ship, coincident with OX at time $t = 0$. Thus the angle $ROX = \omega t$. P is a particle of mass m in motion inside the ship under the action of a force having components (F_r, F_θ) along and perpendicular to OP respectively. The polar co-ordinates of P relative to OR, and therefore as measured by an observer inside the ship, are (r, θ) as shown. Let (r, ϕ) be the polar co-ordinates of P relative to OX and therefore as measured by a non-rotating observer. Then,

$$\phi = \theta + \omega t \quad .. \quad .. \quad .. \quad .. \quad (1)$$

If the fixed observer resolves force and acceleration vectors radially and transversely, he obtains the following equations of motion

$$m(\ddot{r} - r\dot{\phi}^2) = F_r, \quad m(r\ddot{\phi} + 2\dot{r}\dot{\phi}) = F_\theta \quad .. \quad .. \quad (2)$$

Substituting for ϕ from equation (1) and rearranging, these equations may be written

$$m(\ddot{r} - r\dot{\theta}^2) = F_r + 2m\omega r\dot{\theta} + m\omega^2 r \quad .. \quad .. \quad (3)$$

$$m(r\ddot{\theta} + 2\dot{r}\dot{\theta}) = \frac{m}{r}\frac{d}{dt}(r^2\dot{\theta}) = F_\theta - 2m\omega\dot{r} \quad .. \quad .. \quad (4)$$

These are precisely the polar equations of motion which would be written down by an observer within the ship if he were to ignore his rotation and to suppose that the particle was subject to additional forces represented by the additional terms to be found in the right-hand members of equations (3) and (4), *viz.*,

$$2m\omega r\dot{\theta} + m\omega^2 r \text{ radially} \quad .. \quad .. \quad .. \quad (5)$$

$$-2m\omega\dot{r} \text{ transversely} \quad .. \quad .. \quad .. \quad (6)$$

Clearly, these *imaginary* forces are introduced to correct for his neglect of the rotation. Let ψ be the angle made by the direction of motion of P with OP and let v be the velocity of P (referred to the moving frame). Then

$$v\cos\psi = \dot{r}, \quad v\sin\psi = r\dot{\theta} \quad .. \quad .. \quad .. \quad (7)$$

are the polar components of the velocity. Consider now a force of magnitude $2m\omega v$ in a direction at right-angles to the velocity v (*see* Fig. 1). The sense of rotation from the direction of v to that of the force is taken to be opposite to that of the ship's rotation ω. This force has polar components

$$2m\omega v \sin \psi = 2m\omega r\dot{\theta} \text{ radially, } \ldots \quad \ldots \quad \ldots \quad (8)$$

$$-2m\omega v \cos \psi = -2m\omega \dot{r} \text{ transversely } \ldots \quad \ldots \quad (9)$$

It now follows that the "forces" (5) and (6) are equivalent to two other imaginary forces: (*i*) $\omega^2 r$ per unit mass radially, and (*ii*) $2\omega v$ per unit mass at right-angles to the motion. The first is called the *centrifugal* force and the second the *Coriolis* force. Every particle will move relative to the ship, *regarded as stationary*, as though it were acted upon by these two forces in addition to any other forces, such as air resistance, which may be operative.

3. The Centrifugal Field

It will be observed that the Coriolis force vanishes when $v = 0$. Thus, a particle which is in equilibrium within the ship is subjected to a radial centrifugal force alone. This force is proportional to the particle's mass and may therefore be employed to simulate gravity. If the ship's cabin is some distance from the axis of rotation, the lines of centrifugal force will be approximately parallel, as shown in Fig. 2 (*a*), and the simulation of a uniform gravitational field, such as we experience at the Earth's surface, will be excellent. If the floor AB of the cabin is a cylinder with its axis coincident with the axis of rotation, the lines of centrifugal force meet it normally everywhere in the same way that the

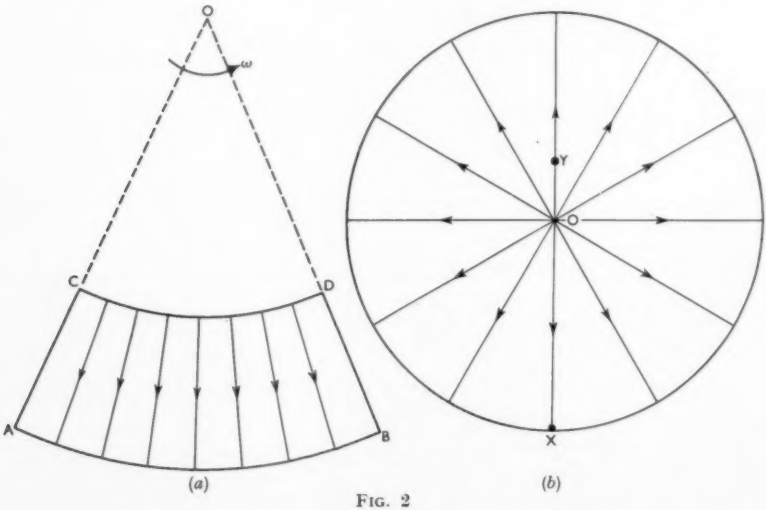

FIG. 2

lines of gravitational force are perpendicular to horizontal ground on Earth. A man walking on the cylindrical surface AB will accordingly experience sensations similar to those felt when he walks on a horizontal surface on Earth. The surfaces of stationary liquids will also be cylindrical and table tops will have to conform to the same shape. Since the centrifugal force is proportional to the distance r from the axis of rotation, its magnitude will be smaller at the ceiling CD than at floor level. This means that a man standing on AB will feel light-headed and that his feet will seem correspondingly heavy, a state which could be corrected by wearing light shoes and a heavy space helmet! It is clear that this effect becomes less appreciable as the distance of the cabin from the axis of rotation is increased.

If the axis of rotation passes through the centre of the cabin as shown in Fig. 2 (*b*), the lines of centrifugal force will radiate from O and conditions will be very different from those experienced on Earth. The floor will be circular and there will be no ceiling. The phenomenon of light-headedness will be very pronounced, or, if the cabin is small, a man may stand with his feet at X and his head at Y and experience the distressing sensation of being upside down with his feet firmly planted on the ground. Weightlessness may very well be preferred to such an anomalous state!

Suppose AB (Fig. 2 (*a*)) is the floor of a compartment in an artificial satellite and that its radius is r ft. If the apparent gravity, at this floor is to equal g, we must choose ω so that:

$$\omega^2 r = g = 32{\cdot}2,$$

$$\text{i.e.,}\quad \omega = 5{\cdot}675 r^{-\frac{1}{2}} \qquad .. \qquad .. \qquad .. \qquad (10)$$

In particular, if $r = 100$ ft., it will be found that:

$$\omega = 0{\cdot}5675 \text{ rad./sec.} = 32^\circ\ 31'/\text{sec.} = 5{\cdot}42 \text{ r.p.m.}$$

The head of a 6-ft. man standing on the floor of the compartment will then be 94 ft. from the axis, and at this distance the centrifugal force is:

$$0{\cdot}5675^2 \times 94 = 30{\cdot}27 \text{ ft./sec.}^2,$$

i.e., there is a decrease in apparent gravity from his feet to his head of nearly 6 per cent. It seems reasonable to suppose that a man would soon become accustomed to this variation, and after a day spent in an upright posture would feel heavy-headed when he lay down to sleep.

4. Coriolis Force

As shown in the previous section, the statics of bodies in the compartment of an artificial satellite can be made to approximate the statics of the same bodies at the Earth's surface very closely. The dynamics of such bodies, on the other hand, will be complicated by the presence of a Coriolis force which is proportional to the body's speed and acts directly across its path so as to deflect its motion. If V is the velocity due to the ship's rotation at a point distant r from the axis, then $V = \omega r$. The ratio of the Coriolis to the centrifugal force at this

point can therefore be written

$$\frac{2\omega v}{\omega^2 r} = \frac{2v}{V} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

In the case of the artificial satellite of radius 100 ft. considered in the last section,

$$V = 0{\cdot}5675 \times 100 = 56{\cdot}75 \text{ ft./sec.}$$

and the Coriolis force is one tenth of gravity (*i.e.*, the centrifugal force) at a speed of 2·84 ft./sec. This is a slow walking pace. Coriolis effects would accordingly be quite appreciable on such a satellite.

If AB (Fig. 2 (*a*)) is the floor of a compartment in the satellite, a man walking from A to B would experience a Coriolis force vertically downwards, *i.e.*, his weight would increase. Walking in the reverse direction, his weight would decrease. Lifting a cup vertically to drink, his arm would be deflected horizontally parallel to AB and, if he resisted this deflecting force, the liquid contained in the cup would tend to spill over the side in this direction. Water being poured from a jug would be deflected in the direction BA, and, after a little time spent on the satellite, a shift of the glass in the appropriate direction to allow for this would become automatic. On return to Earth, the old set of habits would have to be reacquired at the expense, no doubt, of a number of wet tablecloths. Running up or down stairs lying in the plane $ABCD$ would again bring a Coriolis force into action, deflecting the runner against one of the two handrails. A flywheel, spinning in this plane, would be subjected to a couple about an axis in the plane through O, tending to rotate its axle horizontally. An endless belt passing over pulleys on two parallel horizontal shafts lying in the plane $ABCD$, would have its ascending portion deflected horizontally in one sense and its descending portion deflected in the opposite direction with the result that it would tend to jump off the pulleys. However, the period of a pendulum swinging in the plane $ABCD$ would be unaffected by the Coriolis force, for this would always act on the bob along the line of the suspending thread and would only serve to alter the tension.

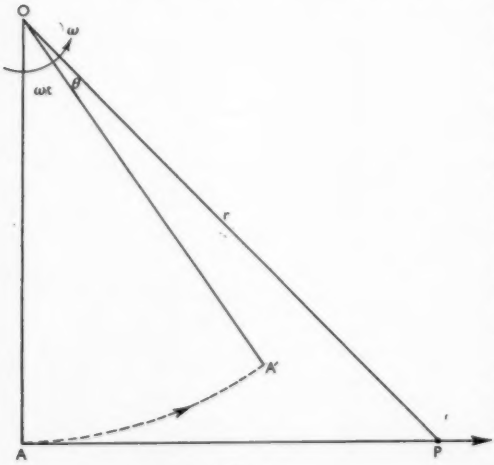

FIG. 3

A body falling freely will no longer move along a straight line. Its path may be calculated by writing down its equations of motion under the action

of the centrifugal and Coriolis forces, but it is simpler to proceed as follows: neglecting air resistance, a particle which is falling freely within the artificial satellite is seen by a non-rotating observer to be moving under no forces. Its track relative to a non-rotating frame is accordingly a straight line described at constant speed. Let A (Fig. 3) be the launching point and AP the track of the particle relative to a non-rotating frame moving with the axis of rotation O of the satellite. For simplicity we shall suppose that the particle is projected horizontally from A so that OA is perpendicular to AP. At time t after projection suppose the particle is at P. The line OA, fixed in the satellite, will have moved into the position OA', where the angle $AOA' = \omega t$. Referring polar co-ordinates appropriate to a rotating frame to the line OA', let (r, θ) be the polar co-ordinates of P. Then, if W is the velocity of projection relative to the rotating frame, the velocity relative to the non-rotating frame at A is $W + a\omega$, where $a = OA$. The particle's speed along its straight track remains at this constant value, and hence:

$$AP = (W + a\omega)t \quad .. \quad .. \quad .. \quad .. \quad (12)$$

It now follows that:

$$\tan(\theta + \omega t) = AP/OA = (W + a\omega)t/a,$$

or
$$\theta = \tan^{-1}\{(W + a\omega)t/a\} - \omega t \quad .. \quad .. \quad (13)$$

Also,
$$r^2 = OA^2 + AP^2,$$

or
$$r = [a^2 + (W + a\omega)^2 t^2]^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (14)$$

Equations (13) and (14) determine the polar co-ordinates of the particle relative to a rotating frame at any time t and hence determine the particle's trajectory within the satellite.

It is convenient to introduce non-dimensional quantities defined thus:

$$\rho = r/a, \quad w = W/a\omega, \quad \tau = \omega t \quad .. \quad .. \quad (15)$$

Then equations (13) and (14) may be written:

$$\left.\begin{aligned} \theta &= \tan^{-1}\{(w + 1)\tau\} - \tau \\ \rho &= [1 + (w + 1)^2\tau^2]^{\frac{1}{2}} \end{aligned}\right\} \quad .. \quad .. \quad .. \quad (16)$$

From these equations, we have plotted particle trajectories for $w = -1{\cdot}0$, $-0{\cdot}5$, $-0{\cdot}2$, 0, $0{\cdot}2$, $0{\cdot}5$, $1{\cdot}0$ (*see* Fig. 4).

Referring to Fig. 4, the effect of the Coriolis force in deflecting the trajectories in the opposite direction to the sense of the rotation is immediately apparent. If the particle is projected in the direction of rotation (positive w), the Coriolis force causes the trajectory to bend back upon itself and the motion is eventually in a sense opposite to that of the rotation. If the particle is projected in the opposite direction (negative w) with a sufficiently large velocity, the Coriolis force may exceed the centrifugal force and the particle will actually rise from the point of projection. $w = 1$ is a particular case when the particle track is a circle with centre O. In this case the velocity of projection just cancels the velocity due to the satellite rotation, and relative to a non-rotating frame the

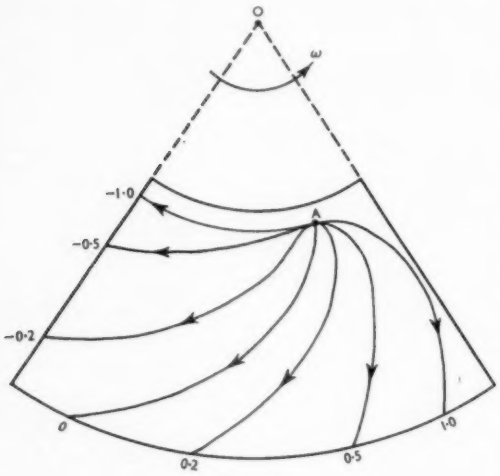

FIG. 4

particle is stationary. The motion relative to the rotating frame is accordingly circular.

5. Conclusions

It is evident that the Coriolis force is highly inconvenient and it is therefore desirable that its magnitude be reduced as far as possible. In the case of an artificial satellite, this can be done by designing it so that the main compartments are as far as possible from the axis of rotation. Thus, if r is the distance of the centre of such a compartment from the axis, the centrifugal force at this point has magnitude ng (i.e., n gravities) if:

$$\omega^2 r = ng \qquad .. \quad .. \quad .. \quad .. \quad (17)$$

The ratio of the Coriolis force at speed v to the centrifugal force is k if

$$2\omega v = kng \qquad .. \quad .. \quad .. \quad .. \quad (18)$$

Eliminating ω between the last two equations, we find that

$$r = 4v^2/k^2 ng \qquad .. \quad .. \quad .. \quad (19)$$

Thus, if we take $v = 3$ ft./sec., $n = 1$, $k = 0{\cdot}05$, r assumes the value 447 ft. If, however, the Coriolis force is to be only 1 per cent. of the centrifugal force, $r = 11{,}200$ ft. Hence, the Coriolis force at walking pace cannot be reduced below about 5 per cent. of the artificial gravity, unless the satellite is of the type comprising two separate bodies connected by a long filament, both bodies rotating about their common mass centre. This is a strong argument in favour of this type of construction. A reduction in the magnitude of the centrifugal force to one less than that of gravity at the Earth's surface does not help matters for, by equation (19) $r \propto 1/n$.

Even if the Coriolis force is reduced to negligible proportions at the ordinary walking pace, it must still be appreciable at speeds common in machinery. However, by proper orientation of the machine so that the direction of motion of a rapidly moving part is parallel to the axis of rotation of the satellite (when the Coriolis force is zero) or by siting the machine near to this axis, this should not prove to be a serious difficulty.

ON THE EQUATION OF ROCKET MOTION*

By G. Leitmann,† Ph.D., Member

SUMMARY

The equation of motion of a rocket is derived from fundamental principles. To permit this derivation the momentum of a time-variant mass is deduced. It is shown that the burn-out velocity of a rocket in field-free vacuum is dependent on the mass flow rate. The resultant expressions are contrasted with those arising from the classical derivation.

I. The Equation of Motion

Before deducing the equation of motion of a rocket, an expression for the linear momentum of a body which loses mass will be derived. Clearly, a rocket is such a body, for it loses mass in the form of gases (or at any rate of mass particles) which leave the rocket with a velocity relative to it.

Consider a set, S, of mass particles whose membership is a function of time, t. Let the mass and position vector (in an inertial reference frame) of the i-th particle of S be denoted by m_i and $\mathbf{r}_i$, respectively. Let $-\Delta m$ be the mass of particles leaving S in time Δt. Denote the position vector of the mass centre of S by $\mathbf{r}_c$ and that of $-\Delta m$ by $\mathbf{r}_L$. The summation over the particles of the set including and excluding, respectively, the particles lost in Δt is indicated by $\overset{S}{\Sigma}$ and $\overset{S-L}{\Sigma}$. Summation over the particles of $-\Delta m$ is denoted by $\overset{L}{\Sigma}$. Thus:

$$\overset{S}{\Sigma} m_i \equiv m = \overset{S-L}{\Sigma} m_i + \overset{L}{\Sigma} m_i$$

$$= \overset{S-L}{\Sigma} m_i - \Delta m \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1.1)$$

Also:

$$\left.\begin{aligned} \mathbf{r}_c(t) &= \frac{\overset{S}{\Sigma} m_i \mathbf{r}_i(t)}{m} \\ \mathbf{r}_c(t+\Delta t) &= \frac{\overset{S-L}{\Sigma} m_i \mathbf{r}_i(t+\Delta t)}{m+\Delta m} \end{aligned}\right\} \quad .. \quad .. \quad .. \quad .. \quad (1.2)$$

and:

$$\mathbf{r}_L(t) = \frac{\overset{L}{\Sigma} m_i \mathbf{r}_i(t)}{-\Delta m} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1.3)$$

From equations (1.1), (1.2), and (1.3) it follows that:

$$\Delta \mathbf{r}_c \overset{S-L}{\Sigma} m_i = \overset{S-L}{\Sigma} m_i \Delta \mathbf{r}_i + \Delta m \left[\mathbf{r}_L(t) - \frac{\overset{S-L}{\Sigma} m_i \mathbf{r}_i(t)}{m} \right] \quad .. \quad .. \quad (1.4)$$

* Manuscript received 1 February 1957. The considerations presented in this paper are abstracted from introductory chapters of the author's doctoral dissertation submitted in partial fulfilment for the Ph.D. degree at the University of California, Berkeley.

† Formerly at U.S. Naval Ordnance Test Station, China Lake, California; now Assistant Professor, College of Engineering, University of California, Berkeley.

Upon division by Δt and letting $\Delta t \to 0$, equation (1.4) yields the linear momentum of set S:

$$\mathbf{p} \equiv \sum_{i}^{s} m_i \frac{d\mathbf{r}_i}{dt} = m \frac{d\mathbf{r}_c}{dt} + (\mathbf{r}_c - \mathbf{r}_L) \frac{dm}{dt} \quad .. \quad .. \quad .. \quad (1.5)$$

Thus, the linear momentum of a set of mass particles subject to mass loss differs from the linear momentum of a time-constant mass by the term $(\mathbf{r}_c - \mathbf{r}_L) \frac{dm}{dt}$. In the derivation given here the existence of a set of mass particles, *i.e.*, of a discontinuous medium, is assumed. An expression identical with equation (1.5) can be deduced for a continuous medium. Such an expression was found by Rankin,[1] albeit by a different technique, and by Diliberto[2] and Ward[3] by a method based on the derivation given here. Manacorda[4] has also given a formula for the linear momentum of a time-variant, continuous medium; his expression can easily be shown to reduce to equation (1.5).

Equation (1.5) will now be applied to the case of a rocket. One considers a rocket to be a set of mass particles bounded by a surface of invariant shape. The rocket loses mass across a portion of its bounding surface, referred to as the exit surface. In the case of a rocket with multiple nozzles, the exit surface consists of several unconnected areas. Fig. 1 shows a rocket at times t and $t + \Delta t$, respectively. At time t, the linear momentum of the system, *i.e.*, the

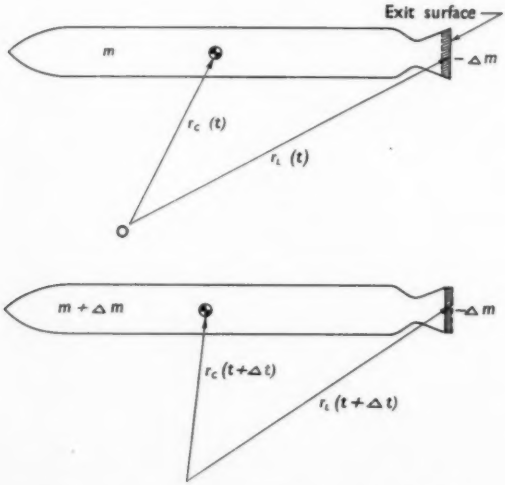

FIG. 1. Rocket configuration at times t and $t + \Delta t$.

rocket including the mass to be expelled in the next Δt, is by equation (1.5):

$$\mathbf{p} = m\mathbf{v} + Q(\mathbf{r}_L - \mathbf{r}_c) \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1.6)$$

where:

$$\mathbf{v} \equiv \frac{d\mathbf{r}_c}{dt}, \quad Q \equiv -\frac{dm}{dt}.$$

At time $t + \Delta t$,

$$\mathbf{p} + \Delta\mathbf{p} = (m + \Delta m)(\mathbf{v} + \Delta\mathbf{v}) + (Q + \Delta Q)(\mathbf{r}_L + \Delta\mathbf{r}_L - \mathbf{r}_c - \Delta\mathbf{r}_c) - \Delta m\mathbf{v}_e \quad (1.7)$$

where $\mathbf{v}_e$ is the velocity of $-\Delta m$†. The rate of change of the linear momentum of the rocket is therefore

$$\frac{d\mathbf{p}}{dt} = m\frac{d\mathbf{v}}{dt} + (\mathbf{r}_L - \mathbf{r}_c)\frac{dQ}{dt} + (\mathbf{v}_e + \frac{d\mathbf{r}_L}{dt} - 2\mathbf{v})Q \quad .. \quad .. \quad (1.8)$$

At time t, $\mathbf{r}_L$ is the position vector of the mass centre of particles about to cross the exit surface; hence, it is the position vector of a point on the exit surface, called the effective centre of the exit surface.

The external forces acting on the rocket may be divided into forces acting on the bounding surface excluding the exit surface, commonly known as aerodynamic forces, and forces due to the pressure difference across the exit surface. In addition, the rocket is, of course, subject to gravity and possibly forces of constraint. If $\mathbf{f}$ is the force per unit area at the exit surface due to pressure above atmospheric pressure, where $\mathbf{f}$ is normal to the exit surface and directed inward, and A is the area of the exit surface (generally assumed plane), and all other forces are denoted by $\mathbf{F}$, then by Newton's second law:

$$m\frac{d\mathbf{v}}{dt} = \mathbf{F} + \int_A \mathbf{f}\,dA - (\mathbf{r}_L - \mathbf{r}_c)\frac{dQ}{dt} - (\mathbf{v}_e + \frac{d\mathbf{r}_L}{dt} - 2\mathbf{v})Q \quad .. \quad (1.9)$$

It is convenient to write equation (1.9) in somewhat different form. Let

$\mathbf{R}_c \equiv$ position vector of rocket mass centre relative to P,

$\mathbf{R}_L \equiv$ position vector of effective centre of exit plane relative to P,

$\mathbf{r}_P \equiv$ position vector of P relative to O,

where P is a point fixed in the rocket, *i.e.*, in the invariant part of the rocket, and O is the origin of the inertial system. If ω is the angular velocity of a reference system fixed in the rocket (with origin P), and $\mathbf{V}_e$ is the velocity of the mass centre of $-\Delta m$ relative to the rocket-based system, the equation of motion becomes:

$$m\frac{d\mathbf{v}}{dt} = \mathbf{F} + \int_A \mathbf{f}\,dA - (\mathbf{R}_L - \mathbf{R}_c)\frac{dQ}{dt} - \\ - \left[\mathbf{V}_e + 2\omega \wedge (\mathbf{R}_L - \mathbf{R}_c) + \frac{\partial \mathbf{R}_L}{\partial t} - 2\frac{\partial \mathbf{R}_c}{\partial t}\right]Q \quad .. \quad (1.10)$$

where $\frac{\partial}{\partial t}$ denotes differentiation with respect to time in the rocket-based system.

† It is assumed here that the exit velocity is invariant over the exit surface.

Equation (1.10) is identical with that derived by Rankin[1] for a continuous medium. In the classical literature, *e.g.*, Rosser *et al.*[5], Sutton,[6] McShane *et al.*,[7] and others, the equation of motion is derived from momentum considerations as was done here. However, classically it has been assumed that the linear momentum of the rocket is given by $m\dfrac{d\mathbf{v}}{dt}$. With that assumption the equation of rocket motion is:

$$m\frac{d\mathbf{v}}{dt} = \mathbf{F} + \int_A \mathbf{f}dA - Q\mathbf{V}_e \quad .. \quad .. \quad .. \quad (1.11)$$

At this point some assumptions are stated, which are retained throughout the remainder of this note. The exit surface is fixed with respect to the time-invariant portion of the rocket. As a consequence of this assumption $\dfrac{\partial \mathbf{R}_L}{\partial t} = 0$. The motion of the mass centre is rectilinear. For a vertically rising rocket this means neglecting the effect of the Earth's rotation. Thus, $\omega = 0$. An effective exhaust velocity:

$$\mathbf{c} \equiv \mathbf{V}_e + Q^{-1}\int_A \mathbf{f}dA$$

is defined and assumed constant. This assumption is made for the sake of simplicity and in the absence of any knowledge of the variation of $\mathbf{V}_e$. Of course, the pressure force $\int_A \mathbf{f}dA$ increases with increasing altitude and Q may be variable. For a perfectly expanded nozzle $\int_A \mathbf{f}dA = 0$ and $\mathbf{c} = \mathbf{V}_e$. At any rate, the pressure force is small compared with $Q\mathbf{V}_e$.

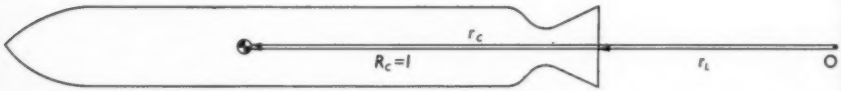

FIG. 2. Rocket coordinate system.

Since one is generally interested in the motion of the rocket as a whole rather than in the motion of the mass centre (which may move internally), the equation of motion will be changed into one describing the motion of a point fixed in the rocket, the effective centre of the exit plane (see Fig. 2). Letting

$$\mathbf{l} \equiv \mathbf{r}_C - \mathbf{r}_L$$

$$\mathbf{r}_L \equiv \mathbf{s}$$

and in view of the assumptions stated above, equation (1.10) becomes:

$$m\ddot{\mathbf{s}} = \mathbf{F} - \mathbf{l}\ddot{m} + (\mathbf{c} - 2\dot{\mathbf{l}})\dot{m} - \ddot{\mathbf{l}}m \quad .. \quad .. \quad (1.12)$$

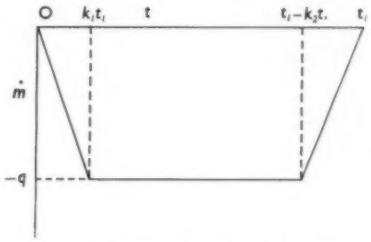

FIG. 3. Trapezoidal mass flow rate.

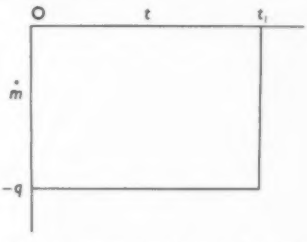

FIG. 4. Rectangular mass flow rate.

where dot denotes differentiation with respect to time. The corresponding classical equation is:

$$m\ddot{\mathbf{s}} = \mathbf{F} + \mathbf{C}\dot{m} \quad .. \quad .. \quad .. \quad .. \quad (1.13).$$

II. The Velocity at Burn-Out

Some aspects of the burn-out velocity will now be discussed. In particular, the problem of allowing the burning time to become small will be investigated. For purposes of this discussion a rocket will be considered in gravity- and drag-free space, since the aerodynamic and gravity effects on burn-out velocity vanish as the burning time becomes small (approaches zero).

For the classical case, equation (1.13), the equation of motion reduces to:

$$m\ddot{s} = -c\dot{m} \quad .. \quad .. \quad .. \quad .. \quad (2.1)$$

whence the burn-out velocity, $\dot{s}_1$, becomes:

$$\dot{s}_1 = \dot{s}_0 + c \ln \frac{m_0}{m_1} \quad .. \quad .. \quad .. \quad (2.2)$$

where conditions at the outset of burning and at burn-out are denoted by subscripts zero and one, respectively. From equation (2.2) it is clear that for the classical case the burn-out velocity is independent of the form of m, hence also of the burning time, t_1.

On the other hand, equation (1.12) is now:

$$m\ddot{s} = -\ddot{l}\dot{m} - (2\dot{l} + c)\dot{m} - \ddot{l}m \quad .. \quad .. \quad (2.3)$$

In order to investigate the burn-out velocity arising from equation (2.3), an assumption of the $\dot{m}$ function is required. The realistic case of trapezoidal mass rate (Fig. 3), and the limiting case of rectangular mass rate (Fig. 4), will be considered.

In the derivation of the flow equations in a rocket motor,[5,6] it is assumed that the velocity of the gases in the rocket's interior is negligible and that the gases attain high exhaust velocity as they pass through the expansion nozzle. For a rocket starting from rest it then follows that $\dot{s}_0$ and $\dot{l}_0$ are zero. Integration of equation (2.3) yields for the case of trapezoidal mass rate

$$\dot{s}_1 = c \ln \frac{m_0}{m_1} + \frac{\bar{l}q_0}{\sqrt{(qm_0k_1t_1/2)}} \tanh^{-1} \sqrt{(qk_1t_1/2m_0)} -$$

$$- \frac{\bar{\bar{l}}q}{\sqrt{(\frac{1}{2}m_-qk_2t_1 - \frac{1}{4}q^2k_2^2t_1^2)}} \tan^{-1} \frac{\sqrt{(\frac{1}{2}m_-q_0k_2t_1 - \frac{1}{4}q^2k_2^2t_1^2)}}{m_- - \frac{1}{2}qk_2t_1} -$$

$$- \frac{2(\bar{\bar{l}} - \bar{l})}{m_-} q - \frac{2(\bar{l} - \bar{\bar{l}})}{m_+} q \quad .. \quad .. \quad (2.4)$$

where $-q$ is the maximum mass flow rate, and subscripts plus and minus denote conditions at $t = k_1t_1$ and $t = t_1 - k_2t_1$, respectively. The mean values of l in the three intervals, $0 \leqslant t \leqslant k_1t_1$, $k_1t_1 < t < t_1 - k_2t_1$, and $t_1 - k_2t_1 \leqslant t \leqslant t_1$, are given by $\bar{l}$, $\bar{\bar{l}}$, and $\bar{\bar{\bar{l}}}$, respectively.

If l = constant, *i.e.*, the mass centre does not move internally, and $k_1 \to 0$, $k_2 \to 0$, *i.e.*, $\dot{m}$ is rectangular (step-function), Fig. 4, equation (2.4) reduces to

$$\dot{s}_1 = c \ln \frac{m_0}{m_1} - l \frac{(m_0 - m_1)^2}{m_0m_1t_1} \quad .. \quad .. \quad .. \quad (2.5)$$

From equation (2.5) it is seen that the burn-out velocity, in field-free vacuum, decreases with decreasing burning time. At first glance it might seem that very short burning times may lead to very small and eventually negative burn-out velocities. This is, of course, absurd. Actually, for real rockets, even those of extremely short burning time, the second term of equation (2.5) amounts to only a fraction of a percent of the first, or classical, term. The question still exists, can $\dot{s}_1 < 0$ ever arise, even theoretically? It is easily shown that it cannot.

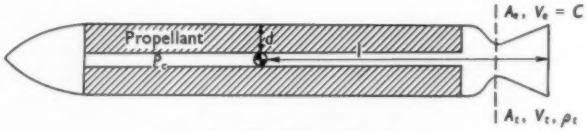

FIG. 5. Rocket configuration.

Errata.—In rocket above d should read $d/2$.

Consider a rocket, Fig. 5, with l = constant. Let

ρ_c = gas density in the chamber
A_t = nozzle throat area
ρ_t = gas density at the nozzle throat
V_t = gas velocity at the nozzle throat
A_e = exit plane area
$V_e = c$ = exit velocity (perfectly expanded).

It is easily seen that

$$(\rho_c)_{\max.} \simeq \frac{m_0 - m_1}{\frac{1}{2}\pi ld^2} \quad .. \quad .. \quad .. \quad (2.6)$$

However, it can be shown[5,6] that

$$\rho_t < \rho_c \quad .. \quad .. \quad .. \quad .. \quad (2.7)$$

i.e.,

$$(\rho_t)_{\max} < \frac{m_0 - m_1}{\frac{1}{2}\pi l d^2} \quad .. \quad .. \quad .. \quad (2.8)$$

Also

$$A_t < \frac{\pi d^2}{4} \quad .. \quad .. \quad .. \quad .. \quad (2.9)$$

and

$$q = A_t \rho_t V_t \quad .. \quad .. \quad .. \quad .. \quad (2.10)$$

so that equation (2.5) may be written:

$$\dot{s}_1 = c \ln \frac{m_0}{m_1} - l A_t \rho_t V_t \frac{m_0 - m_1}{m_0 m_1} \quad .. \quad .. \quad (2.11)$$

But

$$l A_t \rho_t < \frac{l \pi d^2}{4} \frac{m_0 - m_1}{\frac{1}{2}\pi l d^2} = \tfrac{1}{2}(m_0 - m_1) \quad .. \quad .. \quad (2.13)$$

i.e.,

$$l A_t \rho_t V_t \frac{m_0 - m_1}{m_0 m_1} < \tfrac{1}{2} \frac{(m_0 - m_1)^2}{m_0 m_1} V_t < \tfrac{1}{2} \left(\frac{m_0 - m_1}{m_1} \right)^2 V_t \quad (2.14)$$

However,

$$\left(\frac{m_0 - m_1}{m_1} \right)^2 < \ln \frac{m_0}{m_1}, \quad \frac{m_0}{m_1} > 1 \quad .. \quad .. \quad (2.15)$$

and it can be shown[5,6] that

$$V_t < V_e = c \quad .. \quad .. \quad .. \quad .. \quad (2.16)$$

so that

$$c \ln \frac{m_0}{m_1} > l A_t \rho_t V_t \frac{m_0 - m_1}{m_0 m_1} \quad .. \quad .. \quad .. \quad (2.17)$$

This completes the demonstrations that $\dot{s}_1 > 0$ always.

It is concluded that equation (2.3) requires that there exist a finite upper limit to the mass rate $\dot{m}$, or conversely a non-zero lower limit to the burning time t_1. In other words, it is not possible to expend a finite amount of propellent in arbitrarily short time. The classical equation of motion, equation (2.1), imposes no such restriction, permitting the attainment of velocity by instantaneous mass loss.

REFERENCES

(1) R. A. Rankin, *Phil. Trans.*, 1949, [A], **241**, 457.
(2) S. D. Diliberto, "The Rankin-Leitmann Formula." *U.S. Naval Ordnance Test Station (China Lake, Calif.), Tech. Note* 5036–164. **1954**.
(3) L. E. Ward, "Five Mathematical Models of Rockets." *U.S. Naval Ordnance Test Station (China Lake, Calif.), Tech. Note* 3503–3. **1955**.
(4) T. Manacorda, *Riv. Mat. Univ. Parma*, 1952, **3**.
(5) J. B. Rosser, R. R. Newton and G. L. Gross, "The Mathematical Theory of Rocket Flight." **1947**. New York. (McGraw-Hill).
(6) G. P. Sutton, "Rocket Propulsion Elements." **1949**: New York (J. Wiley & Sons).
(7) E. J. Shane *et al.*, "Exterior Ballistics." **1953**: Denver (University of Denver).

THE USE OF PROBE ROCKETS*

By C. A. Cross, M.A., F.R.A.S., Fellow

SUMMARY

Remotely controlled rockets capable of signalling data back to their control bases have been developed during the last ten years to the stage of producing artificial satellites which will be launched within the next twelve months. This paper considers the uses and operation of probe rockets that are not restricted to a closed orbit around the Earth.

Because instruments are expendable no provision need be made for their ultimate safe return to Earth, but difficulties arise from the inflexibility and limited reliability of the instruments and from the finite velocity of light.

Three specific missions are considered in detail: to orbits round the Moon, Mars, and Venus. Conditions for their successful accomplishment are derived, and the information that might be obtained is considered in each case. The prospects for direct investigation of planetary surfaces by remotely controlled landings is examined.

General Considerations

Before we begin to examine specific problems it is perhaps as well to consider the advantages and restrictions which will arise when remotely controlled probe rockets are used to explore the Solar System.

Perhaps the most important difference between a manned vehicle and a probe rocket is the overriding importance of preserving the human pilot's life. The loss of a probe rocket, even with its mission unaccomplished, involves only financial considerations. Thus, costs may be balanced against hazards to enable missions with quite a small individual chance of success to be undertaken. Even for a 50:50 chance of success, there is only one chance in sixteen that all of four separate attempts would fail. We know already that this kind of odds is being faced quite cheerfully in the first probe rocket mission of all, the Vanguard Project, but they would clearly be quite unacceptable with human pilots.

An even more important consequence of the absence of a pilot is that no provision need be made for a return journey. Because of the strictly limited resources of rocket propulsion technique, this fact alone makes the probe rocket the brightest prospect in astronautics. Thus, although we cannot expect to apply the complex procedures of orbital refuelling with a probe rocket, I hope to show that single outward trips to Mars and Venus are feasible now, without the enormous fuel bills which are the outstanding feature of proposals for manned expeditions.

There must be set against these advantages the fact that we obviously cannot envisage the physical return to Earth of specimens or photographic plates. The probe rocket must obtain the desired information, convert it into signals, and transmit these back to us over interplanetary distances. These requirements represent a very considerable development in instrumentation, telemetering, and telecontrol techniques.

Even although these advances involve no impossibilities, there are some quite fundamental limitations to what can be done by probe rockets. Thus, instruments will only do exactly what they are designed to do, and of course

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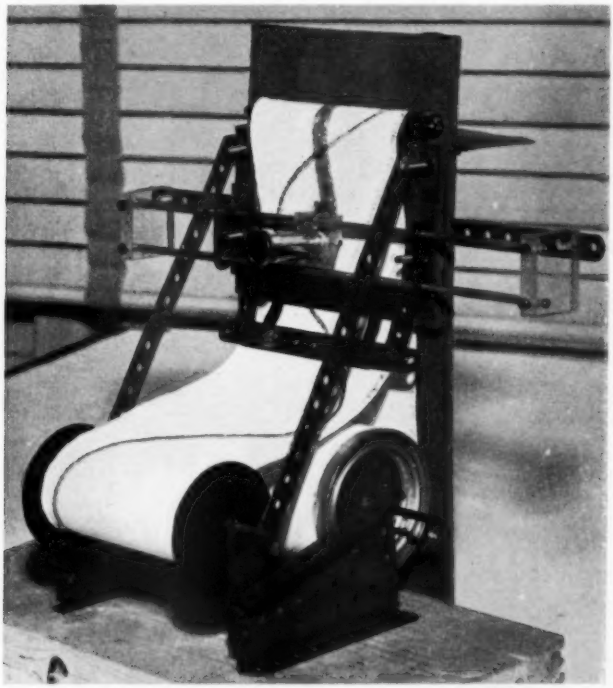

FIG. 1. Apparatus for demonstrating time lag in telecontrol from Earth of an object on the Moon (*rear view*).

we cannot know exactly what will be required of a probe which is exploring an entirely alien environment. Suppose we sent a probe to Mars with the assignment of sampling and analysing the vegetation of the dark areas. It would send us back some peculiar results if there were after all no vegetation.

Then again we must always remember that the velocity of electromagnetic radiation is finite. Even to the Moon there is a "time lag" of 1·3 seconds, and for Mars and Venus at their nearest the time lapse is about 2·5 minutes. These time lags spoil the attractive picture sometimes presented in science fiction stories of the scientist controlling from his home base the activities of some device millions of miles away. Although the existence and effect of these time lags has often been pointed out I do not believe that everyone appreciates how completely disruptive they are. I have therefore arranged a demonstration of the effects encountered in telecontrol of an object on the Moon (Fig. 1 and 2).

By using a paper tape travelling at 0·2 feet per second to carry our signals, instead of radiation travelling at 186,000 miles per second, a 1·3 second lag

FIG. 2. Front view of the time lag apparatus.

is obtained when the stations are only 3 inches apart. The tape is passed downwards behind two slots this distance apart (Fig. 2). The upper slot represents what is happening on the Moon, and the lower the same events as displayed 1·3 seconds later on a TV screen on the Earth. A black line drawn on the tape before the experiment represents an independent variable on the Moon, whilst a red mark is made as the experiment proceeds, and its position may be telecontrolled from the Earth by pushing the slide to and fro (Fig. 1).

This apparatus duplicates all the time lags correctly, and when the pointer is controlled by a person who can only see the "Earth TV" screen, it proves impossible to follow even quite slow changes of the independent variable. Indeed, for a sinusoidal change of period 5·2 seconds the result of attempted control is a similar variation exactly out of phase.

As a final generalization we may consider the associated questions of reliability and complexity. It is already fairly obvious that a probe rocket will be a complex assembly of large numbers of components. Experience[1] in the field of high altitude rockets has already shown that complex experiments have a poorer chance of success than the simple ones. Probe rockets make even greater demands on instrument reliability, for the equipment must survive the launching acceleration, and must then remain operable without maintenance for periods of years in an entirely novel environment. The operation of submarine cable repeaters requires this kind of performance, and the fact that this sort of standard has been attained in the one case encourages us to believe that it will in due course be met in the other.

Transfer Problems

In turning to a more detailed analysis we shall consider the establishment of a probe rocket in a close orbit about three objectives: the Moon, Mars, and Venus.

With a few notable exceptions,[2,3] astronauts have treated the Solar System as being made up of circular coplanar orbits. This is far from being an adequate approximation even for the planets with which we are concerned now. Thus, whilst Venus has a nearly circular orbit, this is tilted so that the planet passes

6·4 million kilometers above and below the plane of the Earth's orbit at each revolution. For Mars the distance from the Sun varies between 206·5 and 249 million kilometers, and again the plane of the orbit is tilted so that it passes some 7 million kilometers above and below the ecliptic. Neglect of these factors would lead to gross error in calculating the transfer orbits, but one simplifying assumption does seem permissible.

The transfer orbits are treated as a succession of two body problems, rather than as a single multi-body problem.[4] The exact multi-body solution can only be worked out by a numerical integration. This is a laborious stepwise procedure, which could only be attempted with the help of a large computer. The approximate method is accurate enough for this paper, although the exact numerical solutions will be needed when probes are actually being launched.

Thus the process of transfer reduces to the following steps:

(1) Escape from the Earth.
(2) Change from Earth orbit to transfer orbit.
(3) Change of plane of transfer orbit at the node line.
(4) Change from transfer orbit to destination planet's orbit.
(5) Descent into final orbit around planet.

In calculating escape and arrival we are concerned only with planetary gravitation, whilst the transfer orbit takes only solar attraction into account.

The great economies to be effected by condensing manoeuvres (1) and (2) into a single initial, and (4) and (5) into a single terminal, velocity change have been recognized,[3,4] but it is not generally realized that the change of plane can also be effected at the same time as the initial velocity change by arranging the departure from the Earth to take place at either the ascending or the descending node of the destination planet's orbit. The saving involved is 1 km./sec. to Mars, and 1·5 km./sec. to Venus, which suffices to make the "node to node" Hohmann elipses the most economical possible.

The velocity changes for the separate and condensed manoeuvres are shown in Table I. For the Moon, complete escape from the Earth's gravitation is not involved, and the initial impulse establishes a transfer orbit in the Earth's own gravitational field.

In order that the probe rocket shall arive at its destination in exactly the correct plane the transfer orbit must start exactly at the nodal point. If the probe starts only one minute before the Earth reaches the ascending node, it will arrive some 100 km. "below" the orbit plane of either Mars or Venus. If it starts after the ascending node it will arrive above the orbit planes (in this context we take the north pole to be above the plane of the ecliptic). Thus, to use the nodal transfer orbits, departures must be restricted to within a few moments of two exact times each year. For 1950 these times were:

Venus 09 hours 10 minutes on June 8th.
17 hours 00 minutes on December 9th.

Mars 05 hours 09 minutes on May 11th.
22 hours 30 minutes on November 12th.

TABLE I

VELOCITY REQUIREMENTS FOR VARIOUS DESTINATIONS

Destination		Velocity for Manoeuvre, km./sec.						Total Characteristic Velocity, km./sec.	Diameter of Final Orbit, km.	Period of Final Orbit, hr.
		Escape	Change to Transfer Orbit	Change of Orbit Plane	Change to Match Planet	Descent to Final Orbit	g Loss at Ascent			
Moon		—	11·7	—	0·83	0·24	1·6	13·9	13,500	40
					0·59					
Mars	A.Node	11.2	2·9	1·0	2·8	0·82	1·6	15·2	10,600	9¼
		11·6			1·98					
	D.Node	11·2	3·0	1·1	2·7	0·76	1·6	15·1	10,600	9¼
		11·7			1·84					
Venus	A.Node	11·2	2·5	1·6	2·7	0·80	1·6	15·2	100,000	97
		11·6			1·84					
	D.Node	11·2	2·9	1·6	3·6	1·06	1·6	15·9	50,000	34
		11·7			2·55					

Because of the precession of the equinoxes, take-off must be 20 minutes earlier each successive year. Moreover, it is not sufficient to depart exactly at any of the specified times, for the destination planet may not be even approximately in the right part of its orbit when the probe arrives. This coincidence is secured on each node every sixteenth year for Venus, and every fifteenth year for Mars.

In considering transfer problems three further points may be made:

(1) The velocity change for the combined manoeuvre of matching velocities and taking up final orbit can be smaller than the single change required to match velocity. If the optimum final orbit is chosen, the combined velocity change is the matching velocity divided by $\sqrt{2}$. The existence of such optimum orbits has been demonstrated by Ehricke.[5] Their diameter and period for these probes are given in Table I. Further economies are possible if two impulses are used upon arrival[6], but they do not justify the complexity involved.

(2) At first sight the accuracy required to operate a probe so that the motors work only for a short burst at the beginning and the end of the flight may seem quite unattainable. However, we have already shown how the final position above or below the orbit plane is determined by selecting the exact time of departure from the Earth. It remains then to fix exactly the velocity and direction of departure.

Using a simple vector analysis we find that for Mars the probe must move faster than the Earth does in its orbit around the Sun by 3·19 km./sec., and in a direction elevated 19·5° from the plane of the ecliptic. For Venus the probe must move more slowly than the Earth by 3·28 km./sec., and with an elevation of 29·5° from the ecliptic plane.

These requirements might be most accurately fulfilled by first establishing the probes in close orbits around the Earth. The orbit planes would be inclined at exactly the required inclination to the ecliptic. Small perturbations of this orbit could then be initiated during the day or two before arrival at the node, so that as the Earth reached the node the rocket would be exactly at the perigee of a hyperbolic orbit receding in the desired direction. The correct departure velocity is then a matter of accurate control of the rocket impulse which starts the probe along this path.

(3) Even with the utmost precision of measurement and control the ideal of two single impulses could only be approached. Error corrections will be needed during the flight.[2] I shall show later how the telemetering equipment could be used to obtain the rocket's position in space, so that deviation from the desired orbit could be detected and put right as soon as possible.

Rocket Propulsion Data

Having calculated the characteristic velocities we are faced with the problem of converting them into rocket design data. This step is essential to a proper understanding of the magnitude of the projects, and yet the complexity of step rocket design is somewhat daunting. The literature does not seem to contain any happy mean between the practical man's approach, as exemplified by von Braun, and the academic approach, by Vertregt.[7]

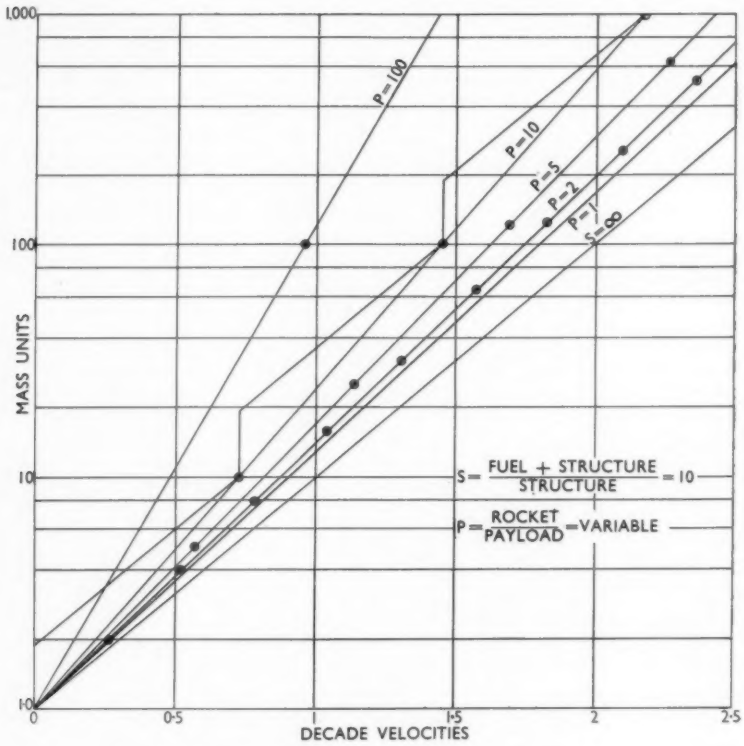

FIG. 3. Graphical construction for design of step rockets.

Use of Fig. 3 *and* 4.

For a rocket S = 5, P = 10, Payload = 1 ton, the first step is made up of: Payload, 1 ton; Structure, 1·8 tons; fuel, 7·2 tons.

Starting at the origin of Fig. 3 (Payload mass = 1 ton), we add the 1·8 tons of structure by moving vertically up the mass axis with no gain in velocity. The 7·2 tons of fuel is added moving parallel to the decade velocity line S = ∞ to give a characteristic velocity for the first step of 0·72 decade velocities.

The next step has 10 tons payload, 18 tons structure and 72 tons fuel, and increases the velocity to 1·44 decade velocities.

Further steps may be marked off on the graph as required.

Although both these authors produce answers that are doubtless quite correct, they do not seem to me to be quite the answers that we need. Von Braun's single numerical solutions give one no insight on the effect of the variables involved, whilst Vertregt's equations seem altogether a too precise and complicated instrument with which to stir up the mud of rocket propulsion.

I would commend a graphical method which was first put forward by von Pirquet in 1933,[8] but appears to have been overlooked in the more recent

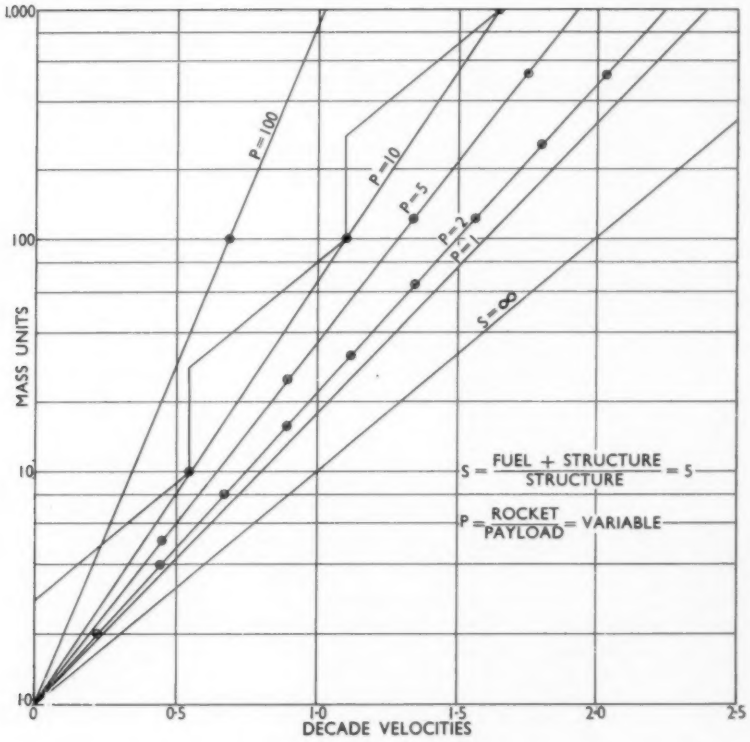

FIG. 4. Graphical construction for design of step rockets (*see note to* Fig. 3).

literature. Only two concepts are involved. The first is the representation of the rocket velocity as a fraction of the "decade velocity," where this is the exhaust velocity times $\log_e 10$. The second concept is the use of a logarithmic scale on which to plot mass.

By the use of decade velocities the diagram is generalized for all exhaust velocities, and the log. scale gives a diagram in which one moves vertically whenever deadweight (tanks, motor, payload, etc.) is considered, and at a constant slope when fuel is being burnt.

Thus Fig. 3 and 4 are almost self-explanatory. For each design one takes the characteristic velocity and the exhaust velocity to obtain the number of decade velocities which the rocket must produce. Then, starting at the bottom left-hand corner with unit payload one simply adds structure weight and fuel in successive steps until the desired decade velocity has been reached, reading

off the masses involved (von Pirquet actually started with the final mass and obtained the amount of payload). Although in Fig. 3 and 4 lines are shown for various fixed payload and structure ratios, the method is completely flexible and the ratios for each step can be varied at will.

Using Fig. 3 and 4, the overall mass ratios may be read off for each of the three missions, considering in each case three exhaust velocities and two structure ratios. A single payload ratio of 5 has been taken throughout, for as long as this ratio is reasonably small the overall mass ratio is not much affected by it. Thus in each case the number of steps is the power to which 5 must be raised in order to obtain the given mass ratio. This large amount of numerical data, presented in Table II, gives a very clear picture of the nature of the rocket propulsion problems, and it embodies all the accuracy which is justified at this stage.

TABLE II

OVERALL MASS RATIOS

Mission	Charcteristic velocity, km./sec.	Overall mass ratio					
		Decade velocity, 5·75 (C = 2·5)		Decade velocity, 6·9 (C = 3·0)		Decade velocity, 8·05 (C = 3·5)	
		S = 5	S = 10	S = 5	S = 10	S = 5	S = 10
Close orbit	9·6	320	100	150	52	72	23
Escape	12·8	2,600	500	710	180	290	90
Moon orbit	13·3	3,500	670	900	230	360	105
Mars orbit	15·1	12,000	1,800	2,500	500	780	200
Venus orbit	15·9	20,000	2,500	3,500	670	1,200	280

C is the exhaust velocity; S is the structure ratio.

In considering Table II we may take one ton as the minimum desirable payload. Then the overall mass ratios become initial masses in tons. If we suppose that 1,000 tons is the largest practicable initial mass, and 250 tons a more desirable value, then we see that the established value of the exhaust velocity is not quite good enough. The small improvement to 3·0 km./sec which is generally accepted in the astronautical literature, suffices to bring all the projects within the scope of a single four-stage vehicle.

Thus the result of the analysis is in marked contrast with the story to which we have become accustomed for manned expeditions, all of which involve the use of orbital refuelling techniques with dozens of vehicles totalling up to hundreds of thousands, or even millions, of tons.

Power and Telemetering

Having established the magnitude of the propulsion problem, we must turn next to the communications requirements. Fortunately the transmission of information is the basis of a thriving industry, and we find that all the techniques we need have been thoroughly explored. Moreover, they seem on the whole to be adequate for our requirements.

At least two papers on the use of wireless waves in interplanetary communication have appeared in the *Journal*,[9,10] and I cannot do better than use the information contained in A. C. Clarke's paper[9] to calculate the power needed for various types of communication channel to Mars at opposition and conjunction (see Table III).

TABLE III

Power for Transmissions from Mars

Distance, km.	Power, watts		
	Telegraphy	Speech	Television
55,000,000 (Opposition)	0·625	625	625,000
400,000,000 (Conjunction)	33	33,000	33,000,000

A very modest reflector area has been assumed on the probe rocket, and the largest practicable receiving area on the Earth. This corresponds with the Jodrell Bank radio telescope, and as it would be necessary to maintain 24-hour contact with the probe we can foresee that the ground installation would consist of three such radio telescopes, distributed at 120° intervals of longitude.

Each ground station would retain control of the probe for an eight-hour shift, handing the probe on to the next station west at the end of this period. The station taking over would lock on their reflector and merely monitor the probe transmission for some time before actually taking over control, so that this would be accomplished without a hitch. It is interesting to realise that with this method of operation the three consecutive shifts at the ground stations would all be at about the same local time. They would all be night shifts for the Mars probe, and day shifts for the Venus probe. Thus the three radio telescopes could handle both missions at once, and still have about eight hours a day for radio astronomy.

As has already been suggested communication would not be limited simply to the reception of telemetered information from the probe. The ground station would also transmit instructions to the probe, so as to effect course corrections during its period of transit, to effect the change to the final orbit upon arrival, and to control the measuring instruments when the probe is established in this orbit. Although the transmission from the ground station to the probe could be made with the same power as is used in the probe transmitter, there is no reason to restrict the power to this minimum value. Considerable economies in the mass and complexity of the receiving apparatus in the probe would result from the transmission of an adequately powerful signal. As the same antennae and reflectors would necessarily be used for reception and transmission at both ends, two different frequencies would be used.

When we examine the way in which electricity could be generated in the probe rocket we can eliminate at once on mass considerations all possibilities except nuclear energy and solar radiation. At first sight nuclear energy

seems ideal, for biological shielding is not needed. A little thought suggests that the payload of delicate radiation-detecting instruments might well require better than biological shields. In any event nuclear energy must at present go through the tiresome stages of thermal and mechanical energy on its way to electricity. We are unlikely ever to see a "chore horse" size nuclear generator capable of running without maintenance for months on end, and these considerations apply with equal force to the conversion of solar power via thermal and mechanical energy.[11]

The best hope for a reliable light-weight power supply is in the methods of direct conversion to electricity, and here the solar energy source is at present well ahead with the Bell silicon wafer solar battery.[12] If the silicon can be protected against deterioration by U.V. light it meets all our requirements. A 17 ft. dia. surface at 10 per cent. efficiency would give between 1·2 and 1·7 kW. electric power as it moved between aphelion and perihelion of the Martian orbit. This suffices (Table III) to maintain a speech circuit for only 100 days at the best opposition, and not at all for the worst. By assuming intermittent operation of the transmitter at 3 kW., Burgess[3] has worked out that a speech circuit could be maintained for 270 days at the best opposition, and 120 days at the worst, out of the 780 days of the Martian synodic period. A telegraphy circuit could be maintained for the remainder of the time.

For the Venus probe the problem is considerably easier, because the probe is nearer to the Sun. Thus a similar power installation would provide 6·3 kW., sufficient to maintain a speech circuit for 240 out of the 584 days of the Venusian synodic period.

Observations

When we consider what might be done with these probes we must always remember that they will have evolved from an extensive series of Earth satellite experiments. During these experiments a great deal of astronomical work will already have been done. The light from all the planets will have been examined spectroscopically, for instance, without interference from absorption in the Earth's atmosphere. We could not justify sending a probe to the planets merely in order to repeat these observations from close to.

These early Earth satellites will not however be capable of directing large aperture telescopes at the planets, and as long as this is so, there will be a strong case for carrying the smaller apertures right out to their targets, where they can resolve the finest detail. Thus a 2 in. dia. telescope 50,000 km. from Mars would be the equivalent of a 2,000 in. telescope in a close orbit around the Earth.

To make use of this resolving power we must be able to transmit the information back to Earth. But we have seen that television is not possible because of the excessive power requirements. Fortunately, so long as we are content with a still picture the information can be handled over a speech-type circuit by the techniques of facsimile transmission. These are currently used to send pictures "by wire" for newspapers. Despite the evidence of everyday usage the system can be adapted to the transmission of high quality pictures.

In this way we could expect a probe placed in an orbit round the Moon to scan a 50-mile strip as the Moon revolved beneath it. The receiver upon the Earth would produce a continuous strip chart resolving detail down to 100 yards diameter. This is not a major improvement upon the photos that we already have for the Moon, but the whole of the Moon would be recorded in plan view, including the limb regions which we only see at very low elevations and the averted region which we never see at all. In order to make the best use of the probe, the pole of its orbit round the Moon would be pointed at the Sun, so that the terminator would be passing continually beneath it.

As well as a complete map the probe could give us information on the existence of a lunar magnetic field, and on cosmic ray intensities.

A probe to Mars could similarly produce a map of the surface with a resolution comparable to our best photos of the Moon. This represents a tremendous improvement on current mapping, which is about as good as naked eye observation of the Moon. The probe could also measure accurately surface temperatures, and by using radar it could make a contour map. Again the magnetic field could be measured, and cosmic ray data could be obtained over the whole journey, to determine the effect of the Sun on these mysterious particles.

With all these considerations in mind we can now visualize the probe (Fig. 5). The large disc carries the solar energy collector plates, and is permanently directed at the Sun except during propulsion. One radio reflector is permanently pointed at the Earth by a locking on device, and the other is combined with an optical scanning telescope to investigate the surface of Mars upon arrival. We may note that the optical scanner is permanently shielded from the Sun by the power generating surface.

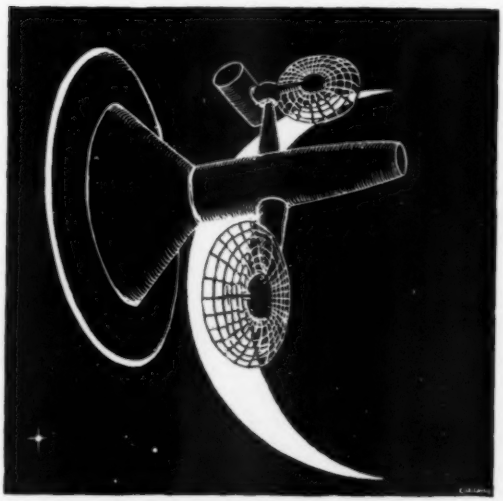

FIG. 5. The Martian Probe.

The probe, depicted in its orbit round Mars, is, of course, the final stage of a three- or four-step rocket. We may suppose that the extensive aerials and the energy collecting surface could in part be accommodated within the large first and second stages, and in part folded up so that they would be protected from the high acceleration and the air resistance encountered at take off. The bulky first stages would then fall back on the Earth,

leaving the probe established in a close orbit just above the effective atmosphere.

At the moment of departure from this orbit the velocity and direction of recession from the Earth would be most accurately and conveniently checked by Earth-based measurements. As the probe receded on its journey the accuracy of these measurements would fall off rapidly. During the journey, therefore, the optical scanner would be used from time to time to produce a complete picture of the zodiacal belt. By measuring the positions of the planets and stars on this picture the exact position of the probe in space would be established, and the orbit could be corrected as required before any small error had accumulated to a serious deviation.

Clearly, with the energy collector locked on to the Sun, and the transmitting/receiving array locked on to the Earth, the attitude of the probe in space is fixed. The automatic controls to achieve this positioning would act upon three flywheels mounted with their axes at right angles to one another. In this way control is effected with expenditure of energy alone, and could be maintained as long as the probe remained operable. Steering jets would only be used immediately after each propulsive effort, in order to remove any residual rotational energy.

The Venus probe would be of similar appearance, but we could only expect information on the cloud forms from optical scanning. Radar scanning would probably provide an adequate picture of the surface relief, and airborne radar displays suggest that the proper techniques would show up any extensive liquid surfaces. Once again the probe could make measurements of magnetic fields and cosmic ray intensities.

Landings

I have reserved until last the most exciting possibility—the landing of probes upon the surfaces of the Moon and planets.

In the case of the Moon, it has often been pointed out that as there is no atmosphere, landings must be effected by rocket retardation. By a fortunate dispensation of nature the absence of an atmosphere implies a low escape velocity, and in fact the characteristic velocity for a mission landing on the Moon is about the same as that for the Mars and Venus orbital probes. Thus the landing of a Lunar probe is not a difficult venture.[13] It is much more difficult to find a useful task for the probe, as there are no gases or liquids for it to sample, and solids are much more difficult to cope with. A higher resolution survey from an orbit may well suggest some useful task. One possibility is in the collection of seismic data, using independent unretarded missiles to initiate shock waves which would be detected by the probe after passage through the Moon's interior. In this way we would obtain information on the internal structure. The probe might also detect the impact of the larger meteors.

For Mars and Venus the escape velocity is too high to permit a single multi-stage rocket to set out from the Earth and land by rocket retardation. But, for the same reason, there are of course atmospheres around these planets. If there is a way of landing by the use of atmospheric resistance, it will have

been worked out long before probes go to Mars and Venus, by experiments in our own atmosphere. Indeed the Vanguard project may supply us with some interesting and unexpected data on this very point.

A great deal of classified work is being done now on the "re-entry problem" with the object of returning loads of explosive safely and accurately to the Earth's surface. We may hope that it will bear fruit in application to space travel problems, for if it is successfully applied to its avowed object the Human race will be in a sorry state.

Although the experts have conflicting views on the severity of the problem[14,15] I feel optimistic about it because of the observed facts about meteor falls. It is not generally realized that if a meteorite is large enough to reach the ground its impact is often quite gentle. The medium-sized meteoric stones do not dig craters with explosive violence, they merely land with a thump and lie upon the surface. When the observer (who is usually a farmer) picks up the stone he finds that it is only comfortably warm to the touch. Indeed there are cases where these stones have subsequently acquired a coating of hoar frost, showing that most of the interior has remained unaffected by the passage through the air.

If this can happen with natural meteorites I feel that it should not be impossible to arrange a similar fate for an artificial projectile.

Let us suppose that we could deposit instrument loads on Mars and Venus by such techniques. Then clearly the loads would be sent down from a satellite which would remain in orbit to act as a relay station passing on the information collected by the ground units.

For the ground units I can make three tentative suggestions:

We might have a chain of self-erecting weather stations, such as have already been developed for dropping by parachute on to inaccessible wastelands.[16] These transmit automatically the normal meteorological data—pressure, temperature, and humidity. They could be specially equipped to measure the rather odd weather that they would encounter in Mars and Venus.

We might have a probe which would sample the fluids, the air on Mars, and on Venus the air and any "seas." The fluids could be analysed by mass spectrograph, as has already been done by a rocket-borne mass spectrograph in the case of our own upper atmosphere.[1]

Finally we might put down a scanning unit to give us a look around by proxy on the surface. When we see the results of such close inspection our probe rocket problems will really begin.

REFERENCES

(1) E. Burgess, *J.B.I.S.*, 1956, **15**, 261.
(2) J. G. Porter, *J.B.I.S.*, 1954, **13**, 68.
(3) E. Burgess, *Aeronautics*, Nov., 1952, **27**, 26.
(4) D. F. Lawden, *J.B.I.S.*, 1955, **14**, 204.
(5) K. A. Ehricke, *Jet Propulsion*, 1954, **24**, 302.
(6) D. F. Lawden, *J.B.I.S.*, 1954, **13**, 27.
(7) M. Vertregt, *J.B.I.S.*, 1956, **15**, 95.
(8) G. von Pirquet, "Manner der Rakete," **1933**, p. 57 *et seq.*
(9) G. O. Smith, *J.B.I.S.*, 1953, **12**, 13.
(10) A. C. Clarke, *J.B.I.S.*, 1948, **7**, 49.

(11) C. A. Cross, *J.B.I.S.*, 1952, **11**, 117.
(12) *Bell Lab. Rec.*, 1954, **32**, 232; *Engineer*, 1954, **197**, 834.
(13) G. H. Clement, *Earth Satellites as Research Vehicles* (*Franklin Institute Monograph No.* 2), **1956**, 14.
(14) R. Cushman, *Aviation Week*, May 14, 1956, **64** (20), 53.
(15) T. Nonweiler, *J.B.I.S.*, 1951, **10**, 258.
(16) J. D. Fahnestock, *Electronics*, Aug., 1951, **24** (8), 232.

TECHNICAL REVIEW

Compiled by E. T. B. SMITH, B.Sc., D.C.Ae., A.M.I.Mech.E., A.F.R.Ae.S., FELLOW

The reviewer was asked recently to devote more space to the subject of electronics. Perhaps he may be pardoned if he interprets this somewhat widely: strictly, the science is confined to the study of the motion of electrons, but it is often the applications which are the more important in their bearing on the problems of travelling in space. In addition, such devices as the transistor and the solid-state Maser do not function in the classical manner of electronic valves or tubes, but these new developments may completely revolutionize long distance radio communication. Anyway, does "electronics" include the propagation of electromagnetic waves in space? No answers will be given to correspondence on this topic.

Advances in Communication and Navigation

Perhaps the most important advance in communication techniques since the transistor will be based on a new family of oscillating and amplifying devices which are known as MASERs (the capitals stand for "Microwave Amplification by Stimulated Emission of Radiation"). A note in *Wireless World*, May, 1957, **63** (5), 212, describes the behaviour of these devices, which depend on the creation of a non-equilibrium distribution of energy between quantum states in atoms or molecules. Energy at the frequency of transition to the equilibrium state can be extracted by stimulation with an applied signal in the form of coherent radiation at the same frequency or of noise. Depending upon the available energy, the device may amplify or oscillate. The first oscillator of this type operated with an ammonia beam with electrostatically separated molecular energy states: it was necessary to use a small beam density to avoid rapid spontaneous transition back to the equilibrium state, and this limited the available output to about 5×10^{-10} watt. A more useful technique would appear to be that in which the loss of equilibrium occurs in the proton or electron spin states in certain solids. The spin produces a magnetic moment which opposes or assists an applied magnetic field, so producing two possible energy states. A non-equilibrium state may be induced by giving the molecule a pulse of coherent radiation which is cut off at a

suitable phase angle, and spin densities much higher than those encountered in the ammonia gas Maser can be obtained. An effective increase may be further achieved by changing from equilibrium to non-equilibrium states at a recurrence frequency of about 10^3 c./s.: also, the spontaneous transition back to the equilibrium state takes place more slowly than in the ammonia beam in some nuclear proton spin states and paramagnetic electron spin states. The frequency of the radiation emitted at transition is proportional to the applied magnetic field, so that the solid state Maser can be tuned over a wide range: this is not the case with the ammonia beam Maser. Bell Telephone Laboratories, Inc., have constructed a solid state Maser, which uses a crystal of gadolinium ethyl sulphate (an ionically bound paramagnetic salt) mounted in a waveguide. This gives a power of about 2×10^{-5} watt at 9,000 Mc./s. when used as an oscillator.

The quantum states of electrons and protons are largely independent of thermal agitation, so that the noise level is equivalent to that in a conventional oscillator or amplifier at a very low temperature of the order of a few degrees Kelvin, and so is some 20 to 30 dB. down on conventional receivers. As it is believed that sufficient gain will be achievable to take advantage of this low noise level, it appears that satisfactory reception could be managed with transmitter power reduced by the same proportion (20 to 30 dB.), or alternatively a great increase in range (10 to 33 times, say) might be obtained. The implications of this are obvious, especially so in the light of some remarks made on communications and radar in TECHNICAL REVIEW in a recent issue of the *Journal*. Radio astronomy would also benefit by the increased range available, and the low noise benefits oscillator stability: variations of not more than one part in 10^{10} are quoted (*Aviation Week*, Feb. 18, 1957, **66** (7), 67).

Navigation systems are being improved to the extent where an aircraft (and presumably a vehicle in space or a satellite) can now find its true velocity relative to the earth entirely with selfcontained apparatus (*Wireless World*, May, 1957, **63** (5), 225–227). The system functions on the Doppler principle, measuring the change in frequency of the back-scattered signal from the Earth as compared with the transmitted signal. Two beams at right angles give the motion along and perpendicular to the axis of the aircraft, and no doubt for large velocity components normal to the reflecting surface a third beam could be used. The main trouble with systems of this type is the transmitter power required: with aerial gain of 120, and a wavelength of 5·7 cm., the total system attenuation, even at 50,000 ft. above the earth, is 145 dB. The noise in the receiver, due to thermal agitations, is such that about 25 watts is needed from the transmitter in this case, so that operation at great ranges would be difficult, even with Maser amplifiers in the receiver. Such a system would probably have some application in solving the problem of docking a vehicle at a satellite port.

Vehicles—High and not so High

Vanguard is perhaps the highest thing we shall see for a few years, so perhaps we should try and keep informed on it. An article by R. L. Stedfeld (*Machine Design*, Nov. 1, 1956, **28** (22), 82–86), gives some details about

the system which may not be familiar to all readers. The rocket stages have been described in the *Journal*, but the gyroscopes used in the inertial reference system have not: the wheels are about 1 in. diameter by $\frac{1}{4}$ in. thick, and run at 12,000 r.p.m., driven by a 400 c./s. A.C. electrical supply, and each unit weighs 4·6 lb. and is 6 in. long by 3 in. diameter. The gimbal system inside the hermetically sealed housing is floated on a viscous fluorinated hydrocarbon oil ("Flurolube") and is located by jewel bearings at the ends, where are also situated the signal pick off units. The principle of floating the gyro in the housing virtually eliminates friction, and the instrument (Minneapolis-Honeywell HIG-6) is stated to measure changes in heading of the order of 0·00003 degrees per second.

The Minitrack phase-difference tracking system is mentioned in the article, which states that the accuracy hoped for is 3 minutes of arc in "normal" conditions and about 20 seconds of arc at small zenith angles or at night. Optical tracking will only be practicable when the sky is dark but the satellite is still in sunshine, that is for about an hour before dawn or after sunset for any observer. Some instrumentation is listed: a relatively unconventional item is an erosion gauge, consisting of a Nichrome film evaporated on to a glass strip in the outer surface of the satellite. As the film becomes eroded by dust and micrometeorites, its resistance will increase. Another is the collision microphone, which is used to record the noise produced on a metal diaphragm in the skin, by impact of small meteoric particles. A storage device records the information between sampling periods in the telemetry system.

A dummy run for the Vanguard launching sequence was performed at the Patrick Air Force Base in Florida on Dec. 8, 1956, when Viking 13 was fired at night (*Jet Propulsion*, Feb., 1957, **27** (2, Part 1), 190, 192). The vehicle was programmed to turn into a horizontal trajectory soon after the vertical launch: it did this successfully, to reach a maximum velocity of about 6,000 ft./sec. and a height of 125 miles, before going into the Atlantic 180 miles from launch. A Minitrack transmitter was ejected at 50 miles altitude and was tracked successfully: the nose-cone was separated after 450 seconds' flight, and during its descent produced satisfactory signals from the meteorological telemetry set and tracking beacon installed in it. The firing was made from the launching gear designed for Vanguard, and this seems to have worked successfully.

Richard W. Porter, Chairman of the Earth Satellite Program Technical Panel, is reported (*Aviation Week*, Feb. 4, 1957, **66** (5), 34) as saying that the Vanguard programme is reasonably on schedule.* He said that tooling for the first stage structure was complete, and that Glenn Martin had made several complete structures. Several General Electric first stage motors (liquid oxygen/ethyl alcohol and gasoline) had been accepted, but one failed: an investigation was proceeding. All the guidance and control components were being tested, and Aerojet had solved a difficult snag in the design of the second stage pressurized-tank propulsion system, which uses red fuming nitric acid and unsymmetrical dimethylhydrazine: the solid-propellent third stage, by

* It was subsequently announced that launching of the first satellite had been postponed to Spring, 1958.—*Editor.*

Grand Central Rocket Corp. or the Allegany Ballistic Laboratory, should be ready on time.

Hypersonic Test Vehicles (HTV), produced by the Aerophysics Development Corp., a Curtiss-Wright subsidiary, are being fired at Holloman Air Development Center, New Mexico (*Aviation Week*, Jan. 7, 1957, **66** (1), 48, 49, 51). The vehicles are intended to reach 10,000 ft./sec. (about 6,800 m.p.h.), and have already achieved about 7,500 ft./sec. at 50,000 ft. Each vehicle costs between 10,000 and 15,000 dollars, and consists basically of a two-stage solid-propellent rocket system with a nose section for payload: the numbers of motors in the stages can be varied to give a flexible range of flight plans. Research work which can be done with HTV's include investigation of the effects of Reynolds Number on heat transfer coefficient and transition from laminar to turbulent flow, perhaps using acoustic pickups for the latter; of the effects on heat transfer coefficient of surface roughness, nose shape, gaseous dissociation, and the ratio of skin temperature to free stream temperature; of the behaviour of boundary layers in hypersonic flow, including shock-boundary layer interaction and boundary layer transition; of upper atmosphere properties; and of the behaviour of materials designed for high temperature use, since the heat transfer rate may exceed that encountered in rocket nozzles. The stagnation pressure at the vehicle nose may reach about 50,000 lb./in.^{2}

The HTV nose cone is made of a glass fibre inner shell and a nickel outer shell, with a silica fibre insulating layer, half an inch thick, between them: the maximum diameter of the cone is 7 in. The nickel shell is fitted with thermocouples on the inner surface.

Data are recorded on a magnetic tape recorder in the nose cone: this instrument records from eight channels, including a time base oscillator. For larger numbers of channels, any of the seven data channels may be shared by a sampling device, which will allow up to 35 channels to be sampled ten times a second each. This recorder weighs only two pounds, and is housed in a shockproof steel case weighing three pounds. This has in it a radioactive "beacon" to aid detection when it falls on the desert. The recorder is fairly shockproof itself, as it will function satisfactorily in an environment of 600 *g* and 200 rad./sec. spin. Power for the recorder comes from a silver/zinc battery weighing 6 oz.

The rocket motors are bonded together, and the fins are bonded to the motors, with epoxy resin. The fins are composite structures, mainly constructed of glass fibre laminates with low-density stabilizing fillers in their hollow interiors. The second-stage fins are thick enough to house small items such as flares and beacons. During descent, the second stage fins are blown off, and the destabilized vehicle falls at about 70 m.p.h. near the ground, which enables the tape and recorder to be salvaged.

The launcher is capable of being used on land or ship, and is used to fire the vehicles either rotating, for low dispersion, in which case the vehicle fins are canted, or nonrotating, in such applications as photography or solar spectroscopy.

NACA hypersonic tests at Wallops Island are also going well: the current (*Aviation Week*, March 11, 1957, **66** (10), 51–53, 55–56, 59, 61) job, apart from

missile testing, is the development of hypersonic glide vehicles, which, at $M=18$ and altitudes of up to 300,000 ft., may be useful man-carrying vehicles. The design characteristics of such gliders may include a nose cone with a high fineness ratio, rather than the blunted nose now associated with the almost-vertical re-entry of ballistic vehicles; variable geometry lifting surfaces, to be very thin at high speeds and to have good lift properties at landing; extreme sweep to the leading edges to reduce heating (60° delta has half the heat input of a straight wing); control by reaction systems (jets) rather than by movable control surfaces; and cooling for the pilot, electronic equipment, and fuel.

Japanese Sounding Rockets have been described by Hideo Itokawa (*Jet Propulsion*, March, 1957, **27** (3), 286–288): this issue also includes much detail on the sounding rockets described at the 11th A.R.S. annual meeting in November, 1956, but these were mentioned in the last issue of the *Journal*. The Japanese workers started with very small rockets: the "Pencil" series were 0·7 in. in diameter and 9 to 12 in. long, and became just transonic. They were used for dispersion tests and launcher development. The larger "Baby" rockets, which were also transonic, were 3 in. in diameter and 3·28 ft. long, and were used for training and equipment development purposes; for data telemetry; and for developing recovery systems for getting the rockets out of the sea. The Pencil and Baby rockets were the forerunners of the present "Kappa" vehicle, which is intended to be used in the I.G.Y. This vehicle is

TABLE I

U.S. Air Force Research Vehicles

Title	Maker	Powerplant	Span, ft.	Length, ft.	Remarks
X–1	Bell	RMI rocket engine, 6,000 lb. thrust	28	35	Reached $M=1·04$ in 1947
X–1A	Bell	As for X–1	28	36	Reached $M=2·5$, 90,000 ft. altitude
X–1B	Bell	As for X–1, pumped propellents	28	40	For heating studies
X–1D	Bell	As for X–1B	28	—	Destroyed during flight in 1951
X–1E	Bell	As for X–1B	28	—	Wings 4 per cent. thick
X–2	Bell	Curtiss-Wright Rocket Engine 15,000 lb. thrust	—	—	Exceeded $M=3$, and 126,000 ft. altitude, crashed in 1956
X–15	North American Aircraft	RMI liquid propellent rocket engine	—	—	Designed for performance above 500,000 ft.; manned
X–17	Lockheed	Three solid propellent rockets	—	—	Three-stage hypersonic unmanned ICBM re-entry test vehicle

5 in. in diameter, 8 ft. long, and gets to $M=2{\cdot}7$ without a booster. The boosted version should get to 80 miles altitude with 15 lb. payload.

Research aircraft are not strictly within TECHNICAL REVIEW's province, but a list is available (*Aviation Week*, Feb. 25, 1957, **66** (8), 175) of the U.S. Air Force's X-series "vehicles". Those which are designed for high-speed, high-altitude flight are as shown in Table I.

Thor, the U.S. Air Force intermediate range ballistic missile, is at present not doing very well: the prototype, fired on Jan. 19, 1957 (*Aviation Week.*, Feb. 4, 1957, **66** (5), **34**), burned to destruction in the air just after launch, apparently due to a "failure of a minor component".

Propulsion Developments

Perhaps the accent in TECHNICAL REVIEW is too much on propulsion for some tastes, but it is contended that until electrogravitics comes along then we shall have to use the brute force method and push our vehicles to wherever we want them to go. This means using rockets—and thermodynamic rockets rather than ion rockets, while we are still in the solar system. For this reason, anything which makes a significant improvement to the performance of rockets is worth mention, whether it enables the propellent specific impulse to be raised, the motor losses to be decreased, or the reliability improved.

Ozone as an oxidant has already been discussed here. However, a note (*Jet Propulsion*, March, 1957, **27** (3), 300–301), gives more details of the substance's properties, as determined by the Armour Research Foundation and the Linde Air Products Corp. Apparently, when ozone is made from oxygen by passing the oxygen through a silent electric discharge with about 10,000 volts between the discharge plates, 34·5 kcal./mole of ozone are absorbed, and the ozone may then be condensed to form a blue nonmagnetic liquid, having the properties shown in Table II; data for liquid oxygen are given for comparison.

TABLE II

COMPARISON BETWEEN PROPERTIES OF OZONE AND OXYGEN

Property	Ozone (O_3)	Oxygen (O_2)
Molecular Weight	48	32
Boiling Point	−111·9° C.	−183·0° C.
Melting Point	−192·8° C.	−218·4° C.
Critical Temperature	− 12·1° C.	−118·4° C.
Critical Pressure	54·6 atm. (abs.)	50·8 atm. (abs.)
Density of Liquid at −183° C.	1·57 g./ml.	1·14 g./ml.

Ozone is extremely toxic: the human safety limit for industrial applications is about 0·1 part per million, but a U.S. Air Force physiologist has survived breathing a concentration of 8 p.p.m.: his breathing capacity was reduced by 50 per cent. afterwards. Ozone is difficult to handle, as it decomposes into oxygen: O_2/O_3 mixtures have only one explosive limit, as opposed to the upper and lower limits for most combustible materials, and at −180°C. or higher

temperatures the safety limit is about 30 per cent. by weight of ozone in oxygen: as the ozone content increases, the explosions become more violent, and it appears that, so far, there is no better solvent for ozone than liquid oxygen. We may compare the way in which acetylene is handled commercially: when compressed strongly enough to be transportable in reasonably small containers, acetylene is very liable to explode, but it can be dissolved in acetone to form a stable solution, at quite a low pressure, having a large apparent density of acetylene.

Returning to ozone, the concentration can vary in storage because of the greater volatility of the oxygen: if an attempt be made to prevent this by refrigeration, the ozone and oxygen may separate out, with further risks. Even the 30 per cent. solution is liable to decompose violently when it is contaminated by dust or other small impurities. Having decided that the risk can be taken, we may enquire how much the specific impulse will increase with ozone: North American Aviation's Rocketdyne Division has found that compared with 260 seconds for liquid oxygen/JP-4, 30ozone-70oxygen and JP-4 will give 275 seconds, 70ozone-30oxygen and JP-4, 280 seconds, and 100 per cent. ozone and JP-4 may give 285 seconds. The reviewer's opinion of all this is that, if you want to dabble with nasty liquids and get good results, why not try fluorine?

Nozzles must be efficient if we have to make use of all the specific impulse that the thermodynamic chemists promise us, and, since 1 per cent of specific impulse means so much in vehicle performance, the best possible form should be given to the nozzle to minimize the losses due to friction and other effects. In a paper presented to the Institution of Mechanical Engineers for written discussion only (summarized in *Chartered Mech.Engr.*, Feb. 1957, **4** (2), 69–71) R. P. Fraser, P. N. Rowe and M. O. Coulter describe a considerable body of work which they have done on the efficiency of small nozzles of various designs intended for rocket engines. They have measured the thrust and mass flow rate (using air from storage cylinders) for "conventional" nozzles of different types. "Conventional" here means nozzles with some degree of blending curvature leading to the throat section, followed immediately by a conical divergent portion of semi-angle between 5° and 90° (a choke). The workers found that a fairly large radius to the entry section was most desirable: with a sharp-edged entry and an exit semi-angle of 10°, the thrust efficiency was 86 per cent. of the "ideal" value, while with a blending radius of twice the throat diameter the thrust efficiency rose to 95·8 per cent .of the "ideal". The optimum semi-angle for the divergent portion was found to be about 8°, for the particular area ratio between exit and throat that was used (6·0), at which angle, with a throat radius of twice the throat diameter, a thrust efficiency of just over 95·8 per cent. was achieved. The "ideal" thrust is based on isentropic non-diverging flow, and the losses are described as being distributed between shock losses, friction losses, and losses due to the exit stream being not parallel. The maximum thrust for any nozzle is taken as occurring when the exit pressure equals the ambient pressure.

Besides the conventional conical nozzles, some consideration has been given to nozzles which have less usual forms. There is something to be gained by

shaping the divergent portion so that no waves form in it and so that the issuing stream is parallel, and this calls for shapes designed by, for example, the method of characteristics: such a nozzle has been made, and there is some likelihood that the efficiency may be increased by one or two per cent. The workers also tested nozzles which consisted of chokes followed by cylinders of larger diameter (augmented chokes), and inverted nozzles, in which the change in flow area is produced by having a suitably shaped plug mounted centrally in a plain cylindrical tube. Both these systems have disadvantages; the augmented choke is not very efficient, and the inverted nozzle presents severe difficulties in cooling it, as well as having high friction losses.

The paper has a useful bibliography, and is well illustrated by shadowgraphs of the flow in and from the experimental nozzles.

TECHNICAL REVIEW is not perhaps a suitable forum for criticism of material in papers, but it should be noted that nozzle research is a field where a number of differing views are held, and that the paper now under notice is an expression of the findings and deductions of one group of workers out of many. For example, an entirely different view of the effects of entry radius is taken by some workers in the U.S.A., and the effects of heat transfer and linear scale have not been touched here.

Screamer is the name Armstrong Siddeley Motors Ltd. gave to their liquid oxygen/kerosene rocket engine for aircraft use. Now that there is no longer any requirement (officially) for an aircraft engine running on liquid oxygen, the Screamer has been declassified, and a highly informative and descriptive paper has been given (*J. R. aero. Soc.*, March, 1957, **60** (555), 181–207) by Sidney Allen. The engine as finally developed used a gas generator, running on the main propellants and with water injection to cool the gas to 920° K., which drove a turbopump system. The combustion chamber was remarkable in that it did not have a throat constriction at all: the exit divergence began at the end of the parallel combustion chamber. The propellants were ignited from a small auxiliary combustion chamber, which was started by spark plugs. A reflection of the difficulty which is inherent in the design of rocket motors for long burning times is that water had to be used as a coolant for the main combustion chamber: this was pumped along the jacket and into the chamber, with film cooling holes being provided at stages along the chamber wall. The flow of kerosene required for the motor's normal operation was inadequate for the proper cooling of a motor of this size (8,000 lb. thrust maximum). The paper describes many stages in the development of the rocket system, and is a valuable account of the difficulties encountered and the way they were overcome.

Materials of construction are of the greatest importance in rocket engines; if we could find a shockproof material that would be strong at 4,000° C., and that could be worked easily, the rocket engine would have many of its difficulties eliminated. As it is, we must do the best we can. An interesting material is molybdenum, which normally suffers from high oxidation losses at elevated temperatures. Molybdenum melts at 2,620° C. (2,900° K.), so that it might be used, with some cooling, in the hot parts of rocket nozzles when coated with such materials as molybdenum disilicide. There is more information

on the protection of molybdenum in a note (*Aviation Week.*, Feb. 4, 1957, **65** (5), 73) on a paper by Dr. C. L. Faust of the Battelle Memorial Institute: he said that suitable choice of a surface barrier would reduce the tendency of molybdenum to diffuse through the coating, and suggested that this diffusion could be prevented by applying a triple electrodeposited layer of chromium/gold/chromium before putting on a final coating of chromium or nickel/chromium.

Flame spraying is a widely used method of applying high-temperature protective coatings, in which the coating medium, in the form of powder, wire, or rod, is passed into a flame, melted, and then blown on to the surface to be protected, where it adheres primarily by a mechanical locking into the irregularities in the metal surface. Subsequent heat treatment can improve the adhesion, but sprayed coatings must always be regarded as less adherent than, for example, electrodeposited films. In *Jet Propulsion*, March, 1957, **27** (3), 306–311) are reviewed techniques used for applying such diverse materials as polyethylene, stainless steel, aluminium oxide, etc. Perhaps one of the most promising techniques is that of the Norton Co., called "Rokide"; it is available in this country. Rokide Z, which consists of 98 per cent. pure zirconium oxide, has a temperature limitation of 2,500° C., and can be applied to practically anything (solder, molybdenum, glass fibre) with good adhesion and very good resistance to corrosion and thermal shock: it has been successfully used for coating rocket nozzles.

Scale procedures are important in rocket engines, where one desires to be able to design a successful large engine from data obtained from models: since one of the largest expenditures in rocket development is that on test facilities, the possibility of having only one large test stand, for proof testing, rather than a number of large development stands for all stages of the work, may mean a reduction in expenditure, in some cases, of millions of pounds. S. S. Penner of Jet Propulsion Laboratory has written a paper entitled "On the Development of Rational Scaling Procedures for Liquid-Fuel Rocket Engines" (*Jet Propulsion*, Feb. 1957, **27** (2, Part 1), 156–161, 168), in which he considers some of the theories which have been put forward by Ross, Crocco, Penner, Tsien and Damköhler. He formulates a programme for experimental work, in which the spray characteristics of the propellents may be scaled to suit the change in linear dimensions, by the introduction of surface-active agents, where one propellent is much more volatile than the other (*e.g.*, liquid oxygen/kerosene), or by scaling the combustion pressure inversely with the linear size. Also, tests should be done in which such similarity criteria as the vibrational driving force, the damping factor, and the chamber Mach number, remain respectively unchanged in a given experimental series. This should enable the effects of the various chemical reaction times, and their dependence on design variables, to be understood far better than is now the case.

The Convair—U.S.A.F. Office of Scientific Research Meeting

The meeting, reported (*Aviation Week*, March 4, 1957, **65** (9), 103–104,108, 111, 113), was attended by some 500 people, and apparently was a great success.

Some notable papers may be summarized as follows:

Ernst Stuhlinger, of Redstone Arsenal, talked about photon rockets, and said that, assuming complete conversion of matter into energy, a trip to a planet would take perhaps two days, with a mass ratio of 1·006, and a trip to Alpha Centauri would take 3·6 years with a mass ratio of 20. These figures assumed a constant acceleration flight of 1 *g* positive followed by 1 *g* negative. Coming to perhaps more practicable systems, he said that ionized alkali metals (rubidium or caesium) might be used to give an exhaust velocity of 80 to 100 km./sec.: a vehicle of 730 tons takeoff weight and 150 tons payload could get to Mars and back in about 3 years, with a mass ratio of 2 and an acceleration of 0·0001 *g*.

Y. C. Lee, of Aerojet, described methods which might be tried for producing copious streams of ions: these included ionization by collision, by electromagnetic radiation, by nuclear reaction, by chemical reaction, by shock tubes, and by surface films in an intense electric field.

G. M. Giannini, of Giannini Research Laboratory, said that he is doing basic research on plasma streams of high density and temperature (10,000° K.), to find what the hydrodynamic laws are for such a material, and has made a "wind" tunnel using plasma for re-entry work. The General Electric Co., U.S.A., has a water-stabilized electric arc which produces a plasma jet for similar re-entry tests for an intercontinental ballistic missile.

Apart from the plasma jets, a lot of time was occupied by the re-entry problem. A. A. Eggers, of Ames Aeronautical Laboratory, described a hypothetical descent of a manned sphere of 5 ft. diameter from a 500-mile high orbit: the speaker thought "a vigorous young Air Force man ought to be able to do it", although the reviewer thinks that not all of us would fold up sufficiently small to go in such a device. However, the sphere is supposed to weigh 630 lb., and have some stabilizing fins, and it would fall from 500 miles to 50 miles in 3 revolutions about the Earth. At 50 miles drag would begin to be experienced, and a skin temperature of not more than 1,700° K. might be reached at 40 miles, if the boundary layer remained laminar. The speed would have been reduced to 400 ft./sec. at 35,000 ft., and a parachute could then be used. E. Van Driest of North American Aviation discussed boundary layer conditions in re-entry, and noted that, when the body temperature was much less than the stagnation temperature, transition from laminar to turbulent flow was delayed significantly, and that surface roughness had less effect on transition as the Mach No. was increased.

Hans A. Lieske, of the Rand Corp., described the accuracy of control needed to get rockets successfully to the Moon. To hit the Moon at all, we would need to get within errors of 40 ft./sec. and $\frac{1}{4}°$, with an initial velocity of 35,000 ft./sec. at 350 miles: to hit the Moon within a given 100 mile radius circle, or put the vehicle into an orbit with an altitude accurate to within 100 miles, we need to be within 2 ft./sec. and 0·01 degree. To send the vehicle to the Moon and back to the Earth with a 1,000 mile landing uncertainty would need guidance to within 0·12 ft./sec. and 0·01°.

CORRESPONDENCE

(In these letters to the Editor, some passages have necessarily been omitted.)

Spherical Space Time and the Special Theory of Relativity

SIR,

I should like to add the following remarks to my recent paper.[1]

If in the case of spherical space time we indicate the cosmical present by $T = \epsilon$, and if we suppose that to a first approximation the expansion has been of linear type since the beginning, then ϵ will be small. Considered from the cosmic point of view, we are then in the direct neighbourhood of the radiant of galactic world lines, $T = 0$. Now for the sake of simplicity let us omit two space dimensions, so that we can represent spherical space time by a spherical surface, of which an octant is indicated in Fig. 1. Then intergalactic space at the cosmical present $T = \epsilon$ is represented by a small circle on the spherical surface with Q ($T = 0$) as centre. The radius QP in arc measure represents the time lapse $T = \epsilon$, and is also equal to the radius of curvature R_{to}.

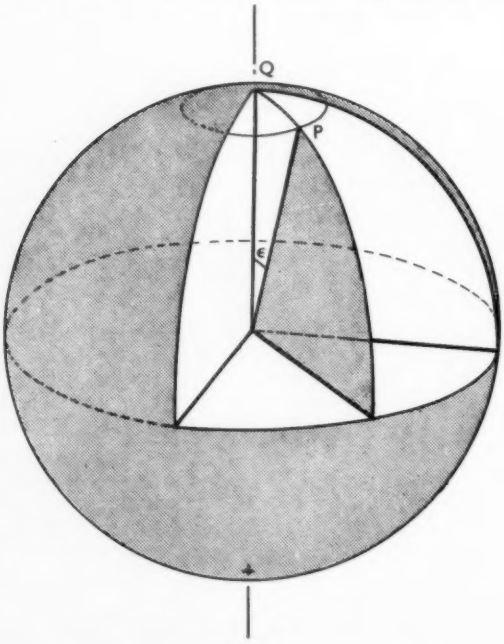

FIG 1.

Now in any small (and therefore flat) region of spherical space time, the space and time interdependences of the special theory of relativity must hold (local deviations due to gravitational fields may be disregarded). Further *time* is certainly not identical with *space*. Nevertheless, the most natural connection between the measure of time and length is given by the fact that light travels 300,000 kilometres in one second. In flat four-dimensional space time (which is neither space nor time) we can accordingly regard one second as equivalent to 300,000 kilometres, or

one year to one light-year. Using these natural units of space and time, we obtain the results of the theory of relativity in the simplest possible form. If we are asked why this is so, we can give no answer. "If we could," Sir James Jeans observed,[2] "we should see far deeper than we now do into the mysteries of nature."

Hence, assuming the beginning of expansion to have occurred $5{\cdot}5 \times 10^9$ years ago,[1] there seems to be some reason to expect that $R_{t_0} \cong 5{\cdot}5 \times 10^9$ light-years. Then in the formulæ of the recent paper[1] we have to put $n = \pi$. The circumference of the present spatial universe would then become $2\pi \times 5{\cdot}5 \times 10^9$ light-years, and its volume $2\pi^2 \times (5{\cdot}5)^3 \times 10^{27}$ (light-years).[3]

Further, if we define a point for which the distribution of the speeds of recession is radially symmetrical *as being at rest*, the question arises as to whether the speed of a material system with respect to the universal substratum defined in this way may have a more essential significance in nature. In connection with suggestions recently advanced by Dr. Sänger,[3] this question may perhaps become of the utmost importance for future interstellar spaceflight.

Finally, the possibility may be advanced that a radiant of galactic world-lines may perhaps only be a crossing of those world-lines in spherical space-time at short distance. Then the "age" of some stellar systems may be larger than the time lapse since the "beginning of expansion."

St. Ignatiusstratt 99a, Breda, Netherlands. J. M. J. Kooy.

REFERENCES

(1) J. M. J. Kooy, *J.B.I.S.*, **1956**, **15**, 248.
(2) Sir James Jeans, "The Mysterious Universe," p. 110. **1931**: Cambridge (Cambridge University Press).
(3) E. Sänger, *VIIth International Astronautical Conference, Paper*, **1956**.

Sociological Aspects of Space Travel

SIR,

A number of points raised in the article[1] by Dr. Wilcox on psychological consequences of space travel have led me to believe that it may also be of value to consider the experience and relationships of the spaceship's crew from a sociological angle.

During the past few years I have been carrying out research in the small face-to-face work groups within large-scale organizations, and the ideas I wish to present here are based on this fieldwork, although it is, of course, necessary to note at the outset that there are considerable differences between the ordinary work group and the crew of a spaceship. In the first place, the work group is, in general, engaged on one of the ordinary common tasks of everyday life—assembly line operation, routine office work, selling, etc.—and these are performed by countless other groups of a similar kind, whereas the space crew, particularly during the first few years of spaceflight, will be a unique group performing a new and hitherto unattempted work task.

A second important difference between the industrial group and the spaceship's crew is that the latter will be associating together on the job continuously over a period of days, weeks, and perhaps sometimes months, whereas most

work groups are together only between 9 a.m. and 5.30 p.m. or during a particular shift, at the end of which time the members of the group break up and go away into a completely different environment.

A third difference which may not at first seem significant but which may have far-reaching sociological consequences is that touched on by Dr. Wilcox when he emphasized the importance of giving the crew members plenty of work to do. In the ordinary work group everyone has a definite occupation for which he is employed and paid, and where there is a commission or a piece-work basis the amount of pay varies according to the amount of effort the individual puts into his work. In such a work group there is also usually an element of competition present—an incentive to achieve more than the next chap and also often to win the approval of immediate superiors and ultimately the "boss" by doing so. In the spaceship, whatever duties may have been allocated for after landing, most of the activity during flight would be in the nature of a "pass-time," since the control of the spaceship would be mainly automatic and the whole trip preplanned in every detail. A certain amount of "making and reporting various observations" would undoubtedly be possible as Dr. Wilcox suggests, but there would be nothing *essential* to do, no necessity for competition, and no means of showing or proving personal ability.

However, in spite of the differences between them, both the ordinary work group and the crew of a spaceship form a similar type of social group. Each consists of a number of people associating together over a period of time for the purpose of carrying out a particular task and it therefore seems likely that some of the results achieved in research on the ordinary work group will also apply to the space-crew, bearing in mind the differences that have been indicated.

The first of the differences noted, namely the uniqueness of the space-crew's task is likely to be a distinct advantage. In analysing the customary attitudes of mind or "social tradition" in large-scale organizations it has become clear that it is of primary importance to the successful functioning of the group that its members should believe that the job they are doing is worth while or that it makes a definite contribution to something worth while in the eyes of the general community. Some work groups do feel this, some do not. Where they do, the belief helps considerably to smooth over any difficulties or hardships resulting from the formal structure and systems of operation. It seems unlikely that anyone volunteering for a space-trip could fail to believe that it would be worth while. However, it is possible that, instead, the motive might be primarily one of either self-advancement or perhaps "escape" (e.g., depicted in Lydia Ragosin's play "Beyond") and in neither case would this be likely to produce altogether satisfactory crew relationships and mutual understanding. Care should therefore be taken to choose members with the right attitude at the outset and also to encourage a firm belief in the value of the job during training.

A second important factor making for group integration and easy interaction may be considered in the light of the length of uninterrupted association of the crew members during spaceflight. In the course of my research in work groups it has become clear that tensions and difficulties arising from the work and type of formal structure may be considerably alleviated and both a sense of unity

and an added interest achieved if the work group forms an integral unit similar in type and size to that of the nuclear family, that is to say if it consists of from between two and eight operatives controlled by an "instrumental" leader who is responsible for establishing and maintaining the group's desired relations to *external* goal-objects and an "expressive" second in command who is concerned with the *internal* affairs of the group and the maintenance of integrative relations between its members. (The terminology used in this distinction is taken from Parsons and Bales.[2]) This seems to fit in with Dr. Wilcox's "expansive" commander and "meticulous" second-in-command. The commander or leader of the group can in this way be like a father to the group, the second-in-command like a mother. Where this pattern exists and the leaders are integrated with a particular group of subordinates, the latter tend to behave like the siblings of a family—the older or more experienced ones take an interest in and guide the younger, less experienced ones, who in turn look to those with a wider experience for help and advice. As a result of the formal structure there is a familiar pattern of relationships which it is easy to adopt and because of this a certain emotional security and satisfaction may be achieved.

Now in view of the facts (firstly, that the "family" pattern seems to be the most satisfactory one for group functioning; secondly, that it is the normal thing for people on leaving work to go home into a "family" environment; thirdly, that most people have had experience of continuous family life in childhood), it seems likely that the best pattern for the lengthy association of crew members necessary in spaceflight is the family one. Here again an attempt should be made both to select and train men so that they are suitable for adopting rôles appropriate to such a pattern and particular attention should be paid to the leader and second man.

Finally, some suggestions in connection with the lack of essential activity during spaceflight. At first sight this seems an unimportant aspect, but may in fact be the most serious obstacle to satisfactory relationships in the spaceship. Both within and between work groups in large-scale organizations I have found that where workers are busy and the work entails continual interruption of each other, likely to give rise to tension and irritation, there tends to arise a customary manner of approach which helps considerably in smoothing over these contacts. It takes the form of an accepted type of joking—a jovial manner of passing the time of day, telling funny stories, etc. This joking approach seems to have a definite link with the fact that the formal structure gives rise to difficulties and tension yet at the same time necessitates the avoidance of strife and disruption of any kind if the group is to continue functioning (*cf.* A. R. Radcliffe-Brown[3] for an account of the part played by joking relationships in simple societies). However, the joking not only smooths over the relationships but also gives pleasurable and relaxing experience to those involved in them, and in the spaceship, in view of the lack of essential work task and lack of any real need to avoid strife, it seems unlikely that there will be any opportunity for this experience. Even if a joking manner did in fact emerge it would seem ridiculously inappropriate and childish in such circumstances. Nevertheless, perhaps some different more appropriate method of approach or special "language" could be introduced and developed in order that

this particular integrative aspect should not be wasted—a method of approach which indicates, without the necessity for making explicit, a mutual understanding of the discomfort, apprehension and possible boredom involved in spaceflight.

These comments are based on a very superficial knowledge of the geographical and formal structure of a spaceship, but will I hope serve to indicate that there are sociological as well as psychological aspects involved in the planning of space ventures.

PAMELA J. BRADNEY.

2A, Maida Avenue, London, W.2.

March 12.

REFERENCES

(1) E. J. Wilcox, *J.B.I.S.*, 1957, **16**, 7.
(2) T Parsons and R. F. Bales, "Family Socialization and Interaction Process." London: Routledge, **1956** (International Library of Sociology and Reconstruction).
(3) A. R. Radcliffe-Brown, "Structure and Function in Primitive Society." London: Cohen and West, **1952**.

Psychological Consequences of Space Travel

SIR,

The article[1] by Dr. Wilcox is principally concerned with medical problems, *i.e.*, the conditions under which neurotic or psychotic breakdown could be expected to occur in the personnel of a spaceship. Although his opinions are presented in a dogmatic way, they are not such as to command agreement from medical men and psychiatrists. The theories on which his views are based and the practical suggestions he makes (*e.g.*, that the crew should carry with them a "canned" group therapist) are equally unrealistic.

The right person from whom to seek advice about the probable effects of psychological stresses in spaceships would be a medical man who has worked with groups of men in conditions which would be some degree comparable, *e.g.*, in submarines, or immured in snow huts through an Arctic winter. Owing to our lack of first-hand knowledge of what everyday life would be in a spaceship, anything he would say would still be provisional and tentative. I should, however, be surprised if he did not think that psychological stresses could be largely ignored if the physiological ones were taken care of, that the best method of avoiding breakdown under unusual conditions would be by previous training, and that the selection of the crew should be left to executive officers rather than psychologists, and done on the basis of capacities demonstrated in real life situations rather than in tests of, say, "meticulousness" or "expansiveness."

Yours, &c.,

E. T. O. SLATER.

19, Hamilton Terrace, London, N.W.8.

March 16.

REFERENCE

(1) E. J. Wilcox, *J.B.I.S.*, 1957, **16**, 7.

TWELFTH ANNUAL GENERAL MEETING

The Twelfth Annual General Meeting of the British Interplanetary Society was held in the Kent Room, Caxton Hall, London, S.W.1, on Saturday, May 18, 1957.

Present:

R. A. Smith (*Chairman of Council*) in the Chair
L. R. Shepherd (*Vice-Chairman*)
A. V. Cleaver (*Past Chairman*)
L. J. Carter (*Secretary*)

and about forty other members of the Society.

The SECRETARY read the notice convening the meeting, which had been printed in the January-March, 1957, *Journal*.

The CHAIRMAN declared the meeting open and delivered his address, which is printed below for the convenience of members unable to be present:

CHAIRMAN'S ADDRESS

Ladies and Gentlemen,

It is with great personal pleasure that I address you tonight for the first time as Chairman of your Council. I am deeply conscious that my colleagues have done me a great honour in electing me to this office in succession to such distinguished and able persons as those who have previously held this position. I am particularly pleased that this should have happened at this juncture because the launching of the Artificial Satellite will mark the opening of a new phase in astronautics, and at the same time bring another phase to its close. I feel some justification in regarding myself as being among the pioneers of astronautics in this country, having been a member of the Council of this Society continuously for twenty years.

It has been one of the great difficulties of this Society that during that time it has had to maintain public interest in a subject which still lies in the womb of the future, and our particular task lay in convincing the world that interplanetary travel is possible for man, not in a remote future referred to a scale of centuries, but in the relatively immediate future within a few decades. This we have had to do without objective proof. With each passing month fresh evidence accumulates to show that the difficulties we saw ahead were real difficulties and that many of the unreasoned fears we sought to counter have proved to be groundless. We stand solidly behind the decisions taken by men of vision and intellectual courage to press forward with experiments which will, I am confident, prove conclusively that man is able, if he wishes, to experiment in and with the universe around him, and will not be confined to the world on which his species germinated.

International Astronautical Federation

It is a matter of regret that the mutual fear and distrust of various powerful Governments has proved the most potent accelerator in the growth of this branch of knowledge, for although this is a possible method of obtaining Government participation, by arguing the immense tactical value of being ahead in rocket research, one would sooner see international co-operation than international rivalry in the advance into space. For this reason your Council has given its full support to the formation and growth of the I.A.F. as a matter of priority, doing everything in its power to promote international co-operation between the various national astronautical movements, in spite of the clouds of misunderstanding which seem inevitably to mar the atmosphere of such international gatherings. That we have been able to do this has depended to a large extent on the part played by your past Chairman and the Society's Secretary, in the face of difficulties and disappointments that would have deterred less energetic and determined men.

I am glad that I was able to attend the Rome Congress this year as an official delegate by virtue of my office, because we had succeeded in obtaining the consent of our Vice-Chairman to accept nomination to the post of President of the Federation if it were offered, in spite of the increasing demands on his leisure which are the inevitable outcome of his professional commitments, and it was fortunate that I was invited to act on the nomination committee that advised his appointment as I was convinced that he would be a good choice on the basis of his ability and integrity, while it would also serve to recognize the major part played by our Society in the earlier stages of the federation's history. It was also a mark of recognition of his past devotion to the best interests of the organization.

It was particularly gratifying to me to have been in attendance at the Session that elected the Russian delegation to full membership status, and subsequently honoured Professor Sedov by electing him one of the Vice-Presidents. I felt this did much to redress the balance of representation and to justify the title "International" while it constituted proof of our recognition of the Russian Academy of Sciences as a body of sufficient standing to warrant representation in a scientific organization of this kind, irrespective of political implications. This step was felt to be consistent with the view that astronautics must develop on a basis of international co-operation. Such co-operation will be both needed and promoted in the development of astronautics. We know that interplanetary flight has begun in a spirit of national rivalry, and in so far as it is healthy rivalry we welcome it, but are glad to note that even at this early date the two major protagonists have agreed to work with the highest degree of co-operation on the International Geophysical Year programme.

So we now have to assess the contribution our country and our Society have to make against this world background. Here we find the superficially depressing situation is not entirely without its reassuring possibilities. In the first place one must not forget that rocket research requires much money and

man-power. It is not surprising, therefore, to find that the major roles are to be played by the two greatest countries, counted on the basis of productive capacity. Our own country, at this particular juncture, has to struggle with the economic consequences of having fought two wars in a single lifetime to defend world liberty, entering each at the beginning and going right through to a victorious conclusion. No other country has done this, and as a consequence no other country has been subjected to such an appalling economic strain. We must accept a realistic appraisal of our capacity. I think that in view of the circumstances, our contribution to the I.G.Y. programme is well considered and will prove effective.

Joint Activities

The Council has been able to conclude its arrangements for a joint symposium to be held at the College of Aeronautics at Cranfield in conjunction with the Royal Aeronautical Society and the College authorities, in the course of which the British I.G.Y. project will come under review. Not only is this timely, but it should do much to enhance the standing of the Society. Once again this has been made possible by the good offices of our past Chairman and our Secretary who have worked with other members of the Council and their friends inside and outside the Society to achieve an excellent result.

Publications

In order to enhance the Society's standing in another direction, we have engaged in new activities in the publication world. We have founded a satellite company to undertake certain publishing duties and to secure many practical advantages for us in financial matters.

You will have seen the leaflet describing our new venture, "Realities of Spaceflight," in which Mr. Carter has collated some of the more important of our past publications into one all-embracing whole, which should be a welcome re-appraisal of the problems on an authoritative basis. At the same time we have acted on a suggestion advanced at the last A.G.M. that we should endeavour to supplement the *Journal* by presentation of our subject in non-technical language. This we have attempted to do in the pages of our new publication *Spaceflight*. This project has placed a further burden on shoulders already overladen, although we took the precaution to appoint a new Editor and Editorial Board. This we felt to be imperative if we were to ensure a new angle of presentation.

This has not evaded the necessity for Mr. Carter to ask to be relieved of the responsibility of editorship of the *Journal* to leave him more free to deal effectively with his other duties and it is with regret that the Council has had to concede to his request to hand over to a successor. I know you will all join with me in thanking Mr. Carter for the excellent way in which he has handled the *Journal* in his long term of office as Editor, and to wish his successor, Mr. G. V. E. Thompson, every success in his new duties.

There are a number of duties which are time-consuming but essential for the smooth running of the public meetings. The Council would be pleased to accept offers of service as "Meeting Stewards" who would be charged with the responsibility of seeing that everything was arranged, running through films beforehand, seeing that the right apparatus was available, handing out notices and answering enquiries at meetings.

This brings me to a point which does not seem to be fully understood. This Society is still administered mainly on a voluntary basis. It is your Society, and will be as good a Society as we can make it with your help. The members are invited to contribute to the *Journal* and to *Spaceflight*. The general standards for these publications are now known to you and we have no intention of relaxing them. The Editor of each publication will be pleased to receive the right kind of material, but suitability is important.

I would also remind you that this is a democratic Society, and as such will benefit by nominations for election to the Council of suitable people, but these nominations should be properly "Seconded" and in the Secretary's hands in plenty of time for the voting papers to be circulated, otherwise the Society is involved in the special cost of circulating the ballot papers individually by post.

The fact that the Society's financial affairs are on a sound footing—in spite of rising costs of booking halls, entertaining speakers, printing and paper, postage and telephone charges, rent, and the cost of supporting the I.A.F., to mention but a few of our Secretary's troubles—is because we exercise the greatest care to restrict unnecessary expense in every direction, but as this is touching on the annual financial report, discussion of which is the essential business of this meeting, I now call on Mr. L. J. Carter to present the report, which has been prepared by the Society's auditors, and authorized by the Council, for discussion and comment.

R. A. SMITH,
Chairman of Council.

Annual Satement of Accounts and Balance Sheet

Mr. L. J. CARTER (Secretary) presented the statement of accounts and balance sheet for the year ended September 30, 1956, which had been circulated in the January-March 1957 *Journal*. Mr. Carter stated that during that year we had been carefully conserving our resources to meet the cost of launching *Spaceflight*. We had been very successful in doing so, but the new venture was going to cost us a great deal, for it meant a 33⅓ per cent. increase in the issue of publications (from six to eight per year), in addition to the other costs which had been forced on us. For that reason, the current year was likely to present a very different picture from the one we were now considering, but at least we had achieved our aim in building up our reserves as much as we could, and he therefore wished to invite a proposal for the acceptance of the accounts from the floor.

In moving the adoption of the accounts, Mr. E. HOPE-JONES (Fellow) said that he was very pleased with the position reported. Mr. E. V. BETTS (Fellow) seconded the motion. The motion was then put to the meeting and carried unanimously.

Auditor

The CHAIRMAN reported that Mr. T. W. Woods, A.S.A.A., who had audited the Society's accounts for many years, had advised the Council that he wished to be relieved of these duties for the future as the work had grown so much and he could no longer give it the time it demanded. Consequently, the Council had considered this fully and decided to recommend that these duties be placed in the hands of a firm of Chartered Accountants, who would not only be in a position to carry out the work adequately, but who could also provide secretarial assistance to help in times of stress. He therefore wished to move that the firm of K. Readhead & Co., Chartered Accountants, be elected the new Auditors of the Society. This was seconded by Dr. L. R. SHEPHERD (Fellow) and carried unanimously.

The Secretary then drew attention to a small point regarding the accounts for the future, and mentioned that the Council had decided that the next accounts should run for a period of 15 months from October 1, 1956, to December 31, 1957, and then subsequently for a period of one year. The reason for the change was to make the Society's financial year and subscription year coincide, and enable a more accurate appraisal of the position for each year to be obtained.

Election of Members of Council

The Chairman then reported that it had proved impossible to issue voting papers in time and it was evident that the period of six weeks for the preparation, despatch, and return of these was quite insufficient nowadays. Accordingly, the Council would ask a later meeting of members to extend the period to twelve weeks, for we were very anxious to ensure the maximum time to allow the return of ballot papers by overseas members. In the present case, he suggested that the ballot paper be issued with the next *Journal*, as a means of saving expense, and that the period of six weeks run from the date of issue. This was proposed by Mr. A. V. CLEAVER (Fellow), seconded by Mr. G. V. E. THOMPSON (Fellow), put to the meeting, and carried unanimously.*

General Discussion of the Affairs of the Society.

Mr. L. J. CARTER (Secretary) reported that the membership position at September 30, 1956, was as follows:

* Since the date of these proceedings, the ballot papers have been issued with the April-June *Journal*. The report of the Scrutineers (Messrs. E. Hope-Jones and A. M. Kunesch) was subsequently presented to the Council and showed that the following members of Council had been elected, with effect from August 3, 1957:

1. Dr. L. R. Shepherd. 2. D. Hurden. 3. D. J. Cashmore. 4. E. T. B. Smith.

We are exceedingly pleased to welcome Messrs. Hurden and Smith to the Council, and would also like to thank those who were not elected on this occasion for their enthusiasm and interest in the Society in allowing their names to be put forward.

As indicated on p. 190, Mr. J. Humphries withdrew his nomination for re-election to the Council prior to the issue of the ballot papers. We should like to take this opportunity of wishing him all success in his new post.

	As at 30.9.1956	*As at 30.9.1955*
Honorary Fellows ..	6	*6*
Fellows	740	*691*
Senior Members ..	17	—
Members	2,050	*2,020*
	2,813	*2,717*

Since September 30, quite a number of Members had transferred to Senior Membership, and there was every indication that the introduction of the new grade was proving highly successful.

The Chairman drew attention to the fact that the membership numbers allotted on joining the Society had now reached the 5,000's. This gave an indication of the loss of members over the years.

Mr. E. HOPE-JONES asked if it was intended to issue another List of Members in the near future. The Chairman replied that this was ruled out for the moment not only on the grounds of expense, but also because the time involved in preparing such a list was prodigious. The alternative really lay between printing either a List of Members or an issue of the *Journal*, for the Society could not afford to do both. The Council felt that most members would prefer to receive the present publications rather than forego any and receive a List of Members in lieu. However, in order to meet the point, the Council had already directed that a list of new members should appear in each issue of the *Journal*, and this had been done since the Nov.-Dec. 1956 issue.

A questioner asked if many copies of the *Journal* and *Spaceflight* were sold outside the Society. The Chairman replied that at present *Spaceflight* was not sold externally, in order to encourage those who wanted to read it to join the Society. The *Journal* was sold outside, but almost exclusively to libraries and other institutions.

On being questioned about the possibility of setting up a Technical Group, the Chairman stated that the difficulty here was lack of response. For example, this point was raised several years ago, but only about twelve replies were received (from members in widely scattered places). However, those who were interested in a technical group were invited to write to the Midlands Branch Secretary, who would put them in touch with the local group which was doing studies of this sort.

The Secretary gave information about the informal meetings which were to be held in London during the summer months.

There being no other business, the Annual General Meeting was ended.

Following the Annual General Meeting, a number of colour transparencies were projected. These had been taken by the Secretary on his journey to and from last year's International Astronautical Congress at Rome, and Mr. Carter gave a commentary upon them and entertained members with an account of the various experiences he had had during the trip. The interest and appreciation of the audience was evident from the applause at the end.

APPENDIX I.—ACTIVITIES OF THE SOCIETY, 1955-1956

ADDRESSES DELIVERED TO THE LONDON MEETINGS OF THE SOCIETY DURING THE SESSION 1955-1956

Saturday, October 1, 1955.

"Introduction to Astronautics," by G. V. E. Thompson, B.Sc., A.R.C.S., A.R.I.C.

A lecture designed to acquaint new members with some of the fundamentals of the subject.

Saturday, November 12, 1955.

"Space Travel and Future Research into the Structure of the Universe," by Dr. Ir. J. M. J. Kooy.

An account of some cosmological theories.

Saturday, December 3, 1955.

"Probing Interplanetary Space," by E. Burgess, F.R.A.S.

Investigation of the upper atmosphere, use of probe rockets for atmospheric studies and astrophysical research, satellite vehicles, and planetary probes.

Saturday, January 7, 1956.

"Evolution of Our Galaxy," by H. P. Wilkins, Ph.D., F.R.A.S.

Theories of the formation of the solar system, evolution of the galaxy in spiral structure and implications of the theory of relativity.

Saturday, February 4, 1956.

"The Planet Mars," by P. Moore, F.R.A.S.

A commentary on recent photographs of the planet. This was followed by a short film show.

Saturday, March 3, 1956.

"Combustion Chambers for Rocket Engines," by Professor A. D. Baxter, M.Eng., M.I.Mech.E., F.R.Ae.S., F.Inst.P.

A discussion of combustion chamber operating conditions and problems from the mechanical engineering point of view, with special emphasis on design limitations and some resulting effects on rocket performance.

Saturday, March 17, 1956.

Annual Dinner, at the Craven Hotel.

Saturday, April 7, 1956.

"Power Supplies and Telemetry for an Instrumented Artificial Satellite."

"I.—Orbital Considerations," by E. C. White.

"II.—Instrumentation and Telemetry," by J. Foley, B.Sc.(Eng.), Grad.I.Mech.E., A.F.R.Ae.S.

"III.—Availability of Power," by R. G. Wilkins.

Saturday, April 21, 1956.

(*a*) Annual General Meeting.

(*b*) "Portable Breathing Apparatus," by T. D. Bourdillon.

A discussion of the design of equipment for use in partial vacua, with an account of experience gained in the Mount Everest expedition.

SYLLABUS OF ACTIVITIES OF THE MIDLANDS BRANCH

Saturday, October 8, 1955.

"Introduction to Astronautics," by D. A. Parish and A. C. Rotherham.

Saturday, November 19, 1955.

"Second Steps in Astronautics," by L. R. Shepherd, B.Sc., Ph.D.

Discusses some of the problems facing us before further stages in astronautics can be successfully attacked.

Saturday, December 10, 1955.

"Pilotage and Navigation of Interplanetary Vehicles," by P. H. Tanner, B.Sc.

Requirements for safe navigation, and some of the methods by which these requirements may be met.

Saturday, January 14, 1956.

"Spaceship Instrumentation," by R. A. Waldron, B.A., Grad.Inst.P.

Instrumentation necessary for communication with the Earth, meteorological and astronomical observations, control of the internal temperature of the spaceship, mapping of unknown territory by radar methods, etc.

Saturday, February 11, 1956.

"Aerodynamic Considerations of an Orbital Rocket," by W. F. Hilton, Ph.D.

Consideration of the stability, etc., of the rocket during the two critical phases, initial take-off and aerodynamic return.

Saturday, March 17, 1956.

"Spaceship Construction," by A. M. Kunesch.

Proposed methods of construction of large reaction-powered vehicles, covering step rockets, expendable tanks, materials, insulation, meteoric protection, overall considerations, and step separation.

Saturday, April 14, 1956.

"Astronautics To-day," by R. B. Beard, Grad.I.Mech.E., Grad.I.Prod.E.

A review of the present position.

Saturday, May 12, 1956.

Branch Annual Business Meeting.

SYLLABUS OF ACTIVITIES OF THE NORTH-WESTERN BRANCH

Saturday, October 10, 1955 (*at Preston*).

"Observatories in Space," by C. A. Cross, M.A.

Discuss the most suitable location for, and possible structure of, an astronomical observatory outside the Earth's atmosphere. The advantages of the observatory and some novel methods of construction.

Saturday, November 12, 1955 (*at Manchester*).

"Planetary Atmospheres," by Professor Z. Kopal, D.Sc., F.R.A.S.

Saturday, December 10, 1955 (*at Manchester*).

"Space Medicine," by C. J. Goodall, M.B., B.S.

A study of medical aspects of space travel.

Saturday, January 14, 1956 (*at Manchester*).

"The Basis of the Disintegration Theory," by G. Fielder, B.Sc.

An account of a method by which the surface of the Moon might have been moulded (a modification of the meteoritic or bombardment theory).

Saturday, February 11, 1956 (*at Manchester*).

(*a*) "An Analogue Computer for the Lunar Landing," by C. A. Cross, M.A.

(*b*) "Effects of Reduced Gravity," by R. J. Boor, A.M.C.T.

(*c*) "A Survey of Guided Missles," by E. Burgess, F.R.A.S.

Saturday, March 17, 1956 (*at Manchester*).

(*a*) "Aerodynamic Drag," by R. J. Boor, A.M.C.T. (Branch Chairman's Address).

(*b*) Branch Business Meeting.

SYLLABUS OF ACTIVITIES OF THE WESTERN BRANCH

Saturday, October 22, 1955.

"Interplanetary Flight," by P. J. Ladd.

A summary of the history of astronautics.

Saturday, November 26, 1955.

"The Major Planets and the Universe," by F. A. Smith.

Saturday, January 28, 1956.

"Factors Governing the Design of Interorbital Vehicles," by G. L. Garthwaite.

Factors affecting the stressing of the frame, optimum sizes of fuel tanks and their construction, controls, etc.

Saturday, February 25, 1956.

Film Show.

Saturday, March 24, 1956.

"Mars," by P. Moore, F.R.A.S.

Saturday, April 28, 1956.

Branch Business Meeting.

SYLLABUS OF ACTIVITIES OF THE PROVISIONAL SCOTTISH BRANCH

Wednesday, October 26, 1955 (*at Edinburgh*).

Film Show. *Destination Moon.*

Thursday, October 27, 1955 (*at Glasgow*).

Film Show. *Destination Moon.*

Friday, November 25, 1955 (*at Glasgow*).

(*a*) "The Necessity of Interplanetary Travel," by A. E. Roy, Ph.D.

(*b*) "The Topography of the Solar System," by M. W. Ovenden, Ph.D.

Wednesday, November 30, 1955 (*at Edinburgh*).
"The Artificial Satellite," by A. E. Roy, Ph.D.

Wednesday, January 25, 1956 (*at Edinburgh*).
Brains Trust.

Friday, January 27, 1956 (*at Glasgow*).
Disputation.
A number of reasoned objections to present ideas on spaceflight were debated.

Wednesday, February 29, 1956 (*at Edinburgh*).
(*a*) "The Necessity of Interplanetary Travel," by A. E. Roy, Ph.D.
(*b*) "The Topography of the Solar System," by M. W. Ovenden, Ph.D.

Friday, March 2, 1956 (*at Glasgow*).
"Moons of the Solar System," by A. E. Roy, Ph.D.

Friday, March 23, 1956 (*at Glasgow*).
"Spaceship Engineering," by P. H. Tanner, B.Sc.

Wednesday, March 28, 1956 (*at Edinburgh*).
"Spaceship Engineering," by P. H. Tanner, B.Sc.

Friday, June 22, 1956 (*at Glasgow*).
Branch Business Meeting.

SYLLABUS OF ACTIVITIES OF THE PROVISIONAL YORKSHIRE BRANCH

Thursday, September 8, 1955 (*at York*).
"The Solar System," by G. E. B. Stephenson.

Saturday, September 17, 1955 (*at Leeds*).
"Sixth International Astronautical Congress: A Report," by L. S. Strickson.

Saturday, September 24, 1955 (*at Sheffield*).
"Sixth International Astronautical Congress: A Report," by L. S. Strickson.

Friday, October 7, 1955 (*at Harrogate*).
"Hydroponics," by S. Keeler.
An account of the possible uses of hydroponics in space.

Saturday, October 15, 1955 (*at Leeds*).
Film Show.

Thursday, November 10, 1955 (*at York*).
Brains Trust.

Saturday, November 19, 1955 (*at Leeds*).
"Some Possible Applications of Electronic Computers in Astronautical Problems," by G. Hollis.

Saturday, November 26, 1955 (*at Sheffield*).
"Some Possible Applications of Electronic Computers in Astronautical Problems," by G. Hollis.

Friday, December 2, 1955 (*at Harrogate*).
Brains Trust.

Saturday, December 17, 1955 (*at Leeds*).
Informal Branch Dinner.

Thursday, January 12, 1956 (*at York*).
Short Paper Evening.

Saturday, January 21, 1956 (*at Leeds*).
"The Moon," by M. C. Metcalfe.

Saturday, January 28, 1956 (*at Sheffield*).
Brains Trust.

Friday, February 3, 1956 (*at Harrogate*).
"The Red Planet," by Miss M. Dyson.
A description of the Planet Mars.

Saturday, February 18, 1956 (*at Leexs*).
"The Red Planet," by Miss M. Dyson.

Thursday, March 8, 1956 (*at York*).
"Progress towards Spaceflight," by L. S. Strickson.

Saturday, March 17, 1956.
Visit to the Jodrell Bank Experimental Station.

Friday, April 6, 1956 (*at Harrogate*).
"Speculations on Extra-Terrestrial Life," by S. S. Kind.

Saturday, April 21, 1956 (*at Leeds*).
Branch Business Meeting.

APPENDIX II.—LIST OF DONATIONS

Donations totalling £334 12s. 3d. were received from 490 members during the year and are gratefully acknowledged.

A list of the donors of amounts of 10s. and over is printed below.

Aldrich, F. N.	Aravadenos, P. S. M.	Awdrey, E. V.
Andrew, E. J.	Arthur, K. B.	Bailey, F. R.

Ballantyre, E. H.
Bancroft, J. J.
Barker, Miss D. M.
Barnet, P. A.
Bason, P. N.
Bates, B. R. E.
Bates, G.
Bates, L. M.
Batzer, D. J.
Beadle, A. R.
Benson, J. C. D.
Beresford, D. G.
Betteley, I. G.
Bialkowski, A.
Black, A. P.
Blair, H. O.
Bonestell, C.
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Boxall, V. S.
Brown, K. L.
Brown, W. W.
Bryher, W.
Butler, J. J.
Bygroves, J. J.
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Camplin, A. B.
Capaldi, G.
Carter, C. V.
Caulkett, S. G.
Cheetham, H.
Christensen, D. T.
Cicognan, O.
Cleaver, A. V.
Cleminson, J.
Coleman, Miss A.
Conquest, G. R. A.
Cooke, W. D.
Costar, V. D.
Cotton, J.
Cutler, D.
Day, V. A.
Denman, R.
Devine, D. J.
Diaz, J. M.
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Duke, S. B.
Durant, F. C.
Edwards, P. F. N.
Ettridge, F. A.
Evans, A.
Evans, L.
Falkner, H. E.
Faran, A.
Fergus, C. R.
Ferriman, V. F.
Fiala, D. F.
Flint, W. O. L.
Ford, D. F.
Foreman, F. M. R.
Freeman, D. A.
Gaythorpe, N. S.
Gordon, J. H.
Greer, A. P.
Grisinger, G. F.
Hales, O. K.
Haley, A. G.
Hall, G. B.
Harris, L. J.
Hayes, W. T.
Heathcock, O. R.
Hedges, A. E.
Hewitt, H. G.
Hingston, W. E.
Hoath, A. C.
Huling, D. R.
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Hurford, C. G.
Huzzen, C.
Hyde, C. J.
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Jenks, J.
Jobson, R. W.
Jones, N. H.
Kiddington, W. A.
Kiernan, E. R.
Kitchie, G. E.
Knape, H.
Knapp-Fisher, G. S.
Knights, B. L.
Knuth, R. G.
Korda, W. D.
Lambah, I.
Lascombe, R. B.
Latham, H. J.
Laws, R. J.
Lawler, J. E.
Lawton, P. A.
Laurie, M. E.
Lepper, G. H.
Lewis, R. T.
Lezard, C. V.
Ludder, D. T.
MacDonald, A. J.
Mallan, L.
Mather, Miss S. M.
McBride, R. E.
McCombie, W.
McCoy, W. J.
McDermot, N. A.
Metcalfe, R. W. J.
Miller, A.
Miller, D. G.
Moore, D.
Morris, H.
Nebel, A.
Nelson, R. A.
O'Callaghan, L.
O'Chee, H.
Ostrander, N. C.
Paul, M. C.
Paul, R. W.
Peacock, G. J.
Pearce, A. L.
Pearce, H.
Pollinger, G. T.
Pope, J. L.
Press, H. A.
Pusovnik, R.
Rawcliffe, A. G.
Redman, W.
Regan, A.
Rendall, L.
Risso, H. R.
Roberts, M. E.
Robertson, F. H.
Robertson, F. J.
Robinson, C.
Robinson, N. P.
Rohrer, W. G.
Russell, T. E.
Sammonds, C. J.
Samuel, S.
Savage, J. H.
Shaw, G. N.
Singer, S. F.
Slagter, R. J.
Smith, H. J.
Smith, R.
Solski, S.
Soucy, W. A.
Sparki, K.
Stobbs, B.
Storherd, J. J.
Strickson, L. S.
Stridiron, L.
Stropko, C. G.
Sutton, I. A. W.
Sykes, W. A.
Tait, A. P.
Taylor, M. J.
Taylor, V.
Thacher, Mrs. R. G.
Thompson, P. T.
Thompson, R.
Tobutt, D. C.
Toon, D. A. J.
Trenchard, P.
Vance, C. F.
Van Hoek, F. H. C.
Van Vlyman, D.
Vereker, C. V. P.
Walmsley, J. H.
Watkins, H. P.
Watson, T. K.
Watt, G. C.
Way, F. H.
Weiss, M. G.
Weissinger, R.
White, W. E.
Wilkins, R. G.
Williams, R.
Wilson, A. F.
Wilson, E.
Wimhurst, J. W.
Winterbourne, J. L.
Woledge, D. F.
Yates, F. L.
Zimmerman, C.

B.I.S. NEWS

Election of Members

The following elections were made at the Council Meeting of April 6, 1957:

Fellows.

ROBERT JOHN ALEXANDER, M.S., 3202, 77th Avenue, District Heights, Maryland, U.S.A.
FRANCIS DAVID BERGER BENNY, B.Sc., 123, Manor Road, Derby.
JOHN ARTHUR CATTLE, 30, Woodhill Crescent, Kenton, Middlesex.
JOHN COBB COOPER, A.B., LL.M., 1, Armour Road, Princeton, N.J., U.S.A.
LESLIE JOHN CROWHURST, 60, Sedlescombe Road, Fulham, London, S.W.6.
GEORGE ALEXANDER ELLIOTT, The Barns, Fenlake, Bedford.
BAUDOUIN M. FRAEYS DE VEUBEKE, 88, voie de Liege, Embourg, Belgium.
ROBERT ARNOLD GILL, 23, Fleet Lane, Queensbury, nr. Bradford, Yorkshire.
JOHN WISDOM HARNED, III, B.A., Lake Shore Club, 850, Lake Shore Drive, Chicago, Ill., U.S.A.
JOHN BRIAN HOLMES, B.Sc. (Eng.), 60, Kimberley Road, Solihull, Warwickshire.
DAVID JOHN HUGGETT, B.Sc., Glen Eyre Hall, Basset, Southampton.
EDWARD CHARLES JACKSON, 30, Hillview Gardens, Kingsbury, London, N.W.9.
ROBERT THOMAS MARTIN, Grad.I.Mech.E., 4, Sherbrook Place, Downfield, Dundee, Scotland.
BRYAN ROSS MICHAEL MUNDEN, B.Sc. (Eng.), 11, Elgar Avenue, Tolworth, Surbiton, Surrey.
ALFRED THOMAS PERKINS, B.Sc., 26, Stonards Hill, Loughton, Essex.
LEONARD HERBERT PETHARD, B.Sc. (Eng.), 27, Hartington Road, Sefton Park, Liverpool, 8.
HENRYK REZLER, 6, Lammas Park Gardens, London, W.5.
HARVEY AUSTIN SHIFFER, LL.B., J.D., B.S., 3101, Pasadena Avenue, Los Angeles, Calif., U.S.A.
ERNEST DOUGLAS TEAGUE, 192, Handside Lane, Welwyn Garden City, Hertfordshire.
HENDRICUS JACOBUS VAN DER MAAS, Dept. of Aer. Engineering, Delft Technological University, Kanaalstratt 10, Delft, Netherlands.

Senior Members.

JOHN HARNEIS GRANT ALLISON, 59, Elm Terrace, Tividale, Dudley, Yorkshire.
WILLIAM VICTOR BALL, 2, Weston Avenue, Aston Brook Street, Birmingham, 6.
GERALD VICTOR FOSTER, 19, Salisbury Road, Barnet, Hertfordshire.
EDGAR FRANCIS MEERHOLZ, P.O. Lyndhurst, Johannesburg, Transvaal, South Africa.
JOHN RICHARD WIMBLE RATHBONE, 2, Ascot Road, Weeping Cross, Stafford, Staffs.

Members.

HAROLD ATKINSON, 47, Trogan Avenue, South Shields, Co. Durham.
JOHN CHARLES BASHER, 44, Western Place, Penryn, Cornwall.
CHRISTOPHER BLESSON, 1, Carlingford Road, Morden, Surrey.
PHILIP E. R. BRICE, B.S., 287, Ocean Avenue, Amityville, L.I., N.Y., U.S.A.
DONALD VERNON CALAMORE, M.S., Box 199, Rosamond, Calif., U.S.A.
DOUGLAS HENRY MERVYN CHANDLER, R.A.F., Bentley Priory, Stanmore, Middlesex.
LUDOVICO CHINCARINI, Via Sandro Gallo 136, Lido Venezia, Italy.
STUART EARL COHEN, 943, Westmoor Road, Winnetka, Ill., U.S.A.
MICHAEL LOUIS CROWE, 5, Pine Grove, Sheringham, Norfolk.
TERRY ROSALIE DAWE, South Hill Lodge, South Hill Avenue, Harrow, Middlesex.
GEORGE DIEDRICH, B.S., 653, Weller Road, Elyria, Ohio, U.S.A.
JAMES ALEXANDER FINLAY, Windgate Farm, Combe Raleigh, Honiton, Devon.
WLADYSLAW FISZDON, ul. Nowowiejska 24/2, Warszara 10, Poland.
JUDITH MARJORIE FORDE, 27739, South Pointe Drive, Grosse Ile, Michigan, U.S.A.
CICELY EDITH FORRESTER, Z.3, Artillery Mansions, Victoria Street, London, S.W.1.
BRIAN ROY FOSTER, 3, The Avenue, Barnet, Hertfordshire.
TREVOR JOHN FRAY, 88, Merrival Road, Beacon Park, Plymouth.
WLADYSLAW GEISLER, Katowice-Ligota, 29 ul. Panewnicka, Poland.

MAURICIO GOMEZ-MAVORGA, Explanada No. 1343, Mexico 10, D.F. Mexico.
NORMAN EDWIN HARDY, Comet Servicing Sqdn., R.A.F., Lyneham, nr. Chippenham, Wiltshire.
BRIAN EDWIN HUGGON, 14, Astbury Avenue, Audenshaw, Manchester.
WALTER JOHN HYBIAK, 4019, West 57th Place, Chicago 29, Ill., U.S.A.
JEFFREY FRANK SISSON JAMIESON, 11, The Rise, Bolton le Sands, nr. Carnforth, Lancashire.
KAY DUANE JEFFERSON, M.S., 1120, North Monterey Street, Alhambra, Calif., U.S.A.
WILLIAM HORACE JESSON, 30, Selby Road, Lostock Estate, Stretford, Manchester.
DAVID TREVOR JONES, 24, Davenport Drive, Brunton Park, Newcastle-on-Tyne, 3.
PETER LEVY, B.Sc. (Eng.), 46, Vivian Way, London, N.2.
JOHN MACKINTOSH, The Quantocks, Dunstar, nr. Minehead, Somerset.
COLIN JOHN MANTHORPE, 80, Mile Cross Road, Norwich, Norfolk.
ALEXANDER McDADE, 46, Darragh Road, Comber, Co. Down, Northern Ireland.
BORGE MICHELSEN, 59, Borrebyvej, Copenhagen, Denmark.
DAVID PARKINSON MILLER, 1, Lowther Terrace, Lytham, Lancashire.
JOHN ROBERT MOON, 4, Bishops' Place, Llandaff, Cardiff.
MATTHEW FRANCIS NASH, "Travellers' Inn," Bantry Road, Bramley, nr. Rotherham, Yorkshire.
DOUGLAS PEDLEY, 50, Norfolk Gardens, Woodsend Estate, Flixton, nr. Manchester.
EUGENE PEPIN, LL.D., 3544, Peel Street, Montreal, Quebec, Canada.
MICHAEL JOHN PRICE, 40, Fairhaven Road, Redhill, Surrey.
COLIN PUGH, B.A., 68, Salisbury Road, Moseley, Birmingham, 13.
BRIAN ARTHUR ROBERTS, 22, A.M.Q., R.A.F., Little Rissington, nr. Cheltenham, Gloucestershire.
HENRY A. ROTH, Junr., 121, Fourth Street, Manhattan Beach, Calif., U.S.A.
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JOHN BERNARD SIMS, 166, Green Lane, Shepperton, Middlesex.
GEORGE BRIAN TEELING, 101, Litherland Crescent, St. Helens, Lancashire.
DAVID WILLIAM ALVA THOMAS, 34, A.M.Q., R.A.F., Shawbury, Shrewsbury, Shropshire.
COLIN REGINALD TYLER, 110, Upper Richmond Road, Putney, London, S.W.15.
FREDERICK CHARLES VENNER, 411, Lylington Road, Highcliffe-on-Sea, Hampshire.
JOHN ANTHONY WAINER, 391, Fleetwood Road, Fleetwood, Lancashire.
PATRICK WALDRON, B.Sc., A.M.I.Mech.E., 19, Orchard Road, Middlesbrough, Yorkshire.
ANTHONY PAUL WARSAW, 9, Hocroft Road, London, N.W.2.
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WALTER NEVILLE WINTER, 2, Ivy Road, Cricklewood, London, N.W.2.
FREDERICK STANLY ZIMNOCH, 67, Briggs Street, Easthampton, Mass., U.S.A.

PERSONAL NOTES

MR. JOHN HUMPHRIES (FELLOW) has left the Ministry of Supply Rocket Propulsion Department, Westcott, and is taking up a post with the United Kingdom Atomic Energy Authority at Dounreay, Caithness. Because of this, Mr. Humphries recently resigned from the Council and withdrew his nomination for re-election; however, he hopes to be able to continue editing the ABSTRACTS section of the *Journal*.

Mr. Humphries has been a Member of Council since 1946, and is the author of the book *Rockets and Guided Missiles*.

Deaths

The Editor regrets to announce the deaths of:

ALFRED GANTER.
EDWARD WHITNEY ROBBINS.
NOAH HAROLD STRICKLAND.

JOINT ACTIVITIES

Eighth International Astronautical Congress

The Agrupación Astronáutica Española have announced that arrangements for the Eighth Congress of the International Astronautical Federation are now nearing completion. The Congress will take place at Barcelona and will continue throughout the week commencing October 6. A provisional programme of events has been drawn up by the A.A.E. and is as follows:

Sunday, October 6

11.00–12.00	Preliminary Meeting of Delegates.
18.00	Informal Reception.

Monday, October 7

9.00–13.00	Council or Committee Meetings.
16.00–18.00	Council Meeting.

Tuesday, October 8

9.00–10.00	Council or Committee Meetings.
11.00–13.00	Official Opening; Press Conference.
16.00–18.00	Council Meeting or Technical Session.

Wednesday, October 9

9.00–13.00	Technical Sessions.
16.00–18.30	,, ,,

Thursday, October 10

Coach Tour to Montserrat.

Friday, October 11

9.00–13.00	Technical Sessions.
16.00–18.30	,, ,,

Saturday, October 12

9.00–13.00	Technical Sessions.
15.30–17.00	,, ,,
Evening	Dinner.

Sunday, October 13

A further tour may be arranged for delegates remaining in Barcelona.

Council and Committee meetings and the technical sessions will be held at the National Centre for Scientific Research. In addition to the above items, film shows will be held on certain evenings, and other functions may be arranged for ladies and others who do not wish to attend all the meetings.

The Congress provides an opportunity for members to listen to and meet leading figures in other astronautical societies. There is also, of course, the knowledge and pleasure to be gained from a visit to a foreign country. Members who attended previous Congresses found the experience well worth while, and there is every expectation that the Barcelona Congress will maintain the previous high standard. It is to be hoped that a strong British delegation will attend.

It will be possible to obtain transport to Barcelona at reduced rates (up to 15 per cent. reduction) if delegates travel in a party. Members who are considering attending the Congress should therefore notify the B.I.S. Secretary without delay. Hotel bookings will be made through Cook's.

ABSTRACTS

Edited by J. HUMPHRIES and J. FOLEY

A list of abbreviations of titles of journals was included with the 1954 index and addenda have been published in subsequent issues of the *Journal*. A further addendum is given below:

Space-Flight Problems. Proceedings of the Fourth International Congress on Astronautics Laubscher, Biel-Bienne, Switzerland.

AERODYNAMICS

(187) **The measurement of the aerodynamic forces on a body of revolution and elementary calculation of their normal component.** H. R. Voellmy. *Space-Flight Problems*, 83–88 (1953). (*In French.*) Measurements were made in a supersonic wind tunnel for five body shapes and compared with calculated values. For large incidences the trailing vortices must be considered to get good agreement. (9 *refs.*)

(188) **Air resistance and kinetic theory of gases at very high altitude.** M. S. Travers. *Mém. Artill. Franç.*, **30**, 167–269, 271–358 (1956). (*In French.*) The paper is divided into five main sections: the density of the upper atmosphere; the influence of the mean free path and molecular emission on the resistance of a projectile of given size; the resistances due to molecular absorption and emission for a projectile of given shape; the evolution of meteorites; and conclusions. The application to astronautical problems and in particular the artificial satellite are dealt with briefly. A series of appendices deals with probability functions; ionization, evaporation and radioactivity produced by high temperatures; entropy and probability. (194 *refs.*)

(189) **Data give estimate for winged missile performance.** K. D. Wood. *Aviation Wk.*, **66** (21) 56–58, 63–67 (*May* 27, 1957). Rapid method of preliminary aerodynamic design of supersonic missiles based on NACA wing-body data. An example of a Mach 2·5 missile with a 500 lb. payload is given.

AIRCRAFT

(190) **Hypersonic glider studied as 'manned missile' hope.** J. S. Butz. *Aviation Wk.*, **66** (11) 72–73, 75, 77 (*March* 18, 1957). Problems involved and possible layouts.

(191) **Simple rocket-powered copter demonstrates use for infantryman.** R. Sweeney. *Aviation Wk.*, **66** (16) 32–33 (*April* 22, 1957). Description of Rotor-Craft Pinwheel one-man helicopter.

(192) **Rocket power for one.** H. Levy. *Aeroplane*, **92**, 670 (*May* 10, 1957). Description of Rotor-Craft Pinwheel one-man helicopter which uses two tip-mounted hydrogen peroxide rocket engines to drive the rotor.

ASTRONAUTICS

(*See also* Abstracts nos. 202 and 214)

(193) **Margin for error.** M. W. Rosen and R. B. Snodgrass. *Space-Flight Problems*, 60–62 (1953). Three proposals for satellite launching rockets are examined critically. Residual fuels in tanks at all-burnt can make a large difference to estimated performance. (3 *refs.*)

(194) **Earth scanning techniques for a small orbital rocket vehicle.** K. R. Stehling. *Space-Flight Problems*, 63–70 (1953). Compares radar and optical methods of detecting targets such as industrial plants from a satellite weighing 1,000 lb. in orbit at 500 miles height. (10 *refs.*)

(195) **Cosmic navigation.** V. Dobronravov. *Nauka i Zhizn*, **23** (10) 19–22 (*Oct.* 1956). (*In Russian.*)

CHEMISTRY

(196) **Research on the properties of ozone, 1950–1955.** *Linde Air Products Co., Final Report,* 75 pp. (*May* 1955).

MATERIALS

(197) **Ceramic materials for rocket engines.** *Sprechsaal Keram. Glass Email,* **89,** 414–16 (1956). (*In German.*) Use in combustion chambers and nozzles.

(198) **Plastics stand heat, grow in missile use.** I. Stone. *Aviation Wk.,* **66** (13), 71–73 (*April* 1, 1957). Uses in rocket motors and structures.

PROJECTILES

(*See also* Abstract no. 189)

(199) **Launcher to weigh missile, test thrust.** J. S. Butz. *Aviation Wk.,* **66** (14), 50–51 (*April* 8, 1957). Proposed design of a launcher for large ballistic missiles which weighs missile to $\pm 0{\cdot}1$ per cent. and measures thrust both during test runs and at take-off.

(200) **Hand-picked team develops Jupiter.** D. A. Anderton. *Aviation Wk.,* **66** (15), 50–52, 57, 59, 63, 65 (*April* 15, 1957). Description of facilities and future expansion at Army Ballistic Missile Agency.

(201) **Thoughts on British missiles.** *Flight,* **71,** 623–25 (*May* 10, 1957). Review of information released during the current year.

RADIO AND ELECTRONICS

(202) **The application of radio interferometry to the guidance of interplanetary rockets.** M. J. Golay. *Space-Flight Problems,* 71–74 (1953). Describes a method by which position can be determined to 1 part in 10^7 and velocity to 1 part in 10^4 for interplanetary journeys such as that from Earth to Mars.

ROCKET MOTORS

(*See also* Abstract no. 197)

(203) **On the problem of cooling atomic rockets, with applications to thermonuclear reactions.** H. J. Kaeppeler. *Space-Flight Problems,* 41–59 (1953). (*In German.*) Describes the difficulty of maintaining a nuclear reaction within the confines of an engineering structure. A rotating inward flow is proposed as a means of supplying fluid to the reaction zone. (22 *refs.*)

(204) **On the theory of photon rockets.** E. Sänger. *Space-Flight Problems,* 32–40 (1953). (*In German.*) Derives the fundamental energy relations for rockets using ion and photon discharges, and compares them with those for chemical and working-fluid nuclear rockets.

(205) **On the thermodynamics of working gases for atomic rockets.** I. Sänger-Bredt. *Space-Flight Problems,* 19–31 (1953). (*In German.*) Discusses the temperatures and pressures at which atomic rockets must work and the effects of dissociation and ionisation on the properties of working fluids. The properties of steam are described and detailed information is given in the form of charts which extend to temperatures of 10,000°K. and from 10^{-5} to 10^{+2} atmospheres. (12 *refs.*)

(206) **Rocket test analysis, performance, design calculations with equilibrium gas composition, using Mollier charts.** F. R. Weymouth. *Bell Aircraft Corp. Rept.* 59-982-003, 108 pp. (*April,* 1954).

(207) **On the possibility of applying thermonuclear reactions to rocket propulsion.** I. Schechtman and E. Larisch. *Institute of Atomic Physics, Bucharest, Rept. No. IFA/ET/26,* 21 pp. (1956). It is shown that with steady operation the temperature gradient through the working fluid would be too low to allow the construction of a practical motor. An intermittent motor however might be possible. (10 *refs.*)

(208) **On electrical propulsion of space-ships.** E. Stuhlinger. *Elektronische Rundschau,* **10,** 280–83 (1956). (*In German.*) The production of thrust by accelerating a stream of caesium or rubidium ions by an electric field. Energy is obtained from solar radiation.

(209) **Low-frequency combustion instability in bipropellant rocket motors—experimental study.** M. Barrère and A. Moutet. *Jet Propulsion*, **26**, 9–19 (Jan., 1956). After a description of the phenomena observed in low-frequency instabilities, experimental methods are presented especially the short-time response measurement devices. The first experimental results obtained with circular and rectangular section chambers are described These tend to confirm theory—so long as the working pressure is not varied. (12 *refs.*)

(210) **Measurements of the combustion time lag in a liquid bipropellant rocket motor.** L. Crocco, J. Grey and G. B. Matthews. *Jet Propulsion*, **26**, 20–25 (*Jan.*, 1956). Presents preliminary results of tests on a liquid oxygen/ethyl alcohol motor to determine the combustion chamber transfer function. (15 *refs.*)

(211) **Experimental aspects of rocket system stability.** Y. C. Lee, A. M. Pickles and C. C. Miesse. *Jet Propulsion*, **26**, 34–39 (*Jan.*, 1956). The relative effects of various devices (orifice, inductive venturi, flexible hose, distributed capacitance core) and of different propellants on low-frequency instability were determined experimentally by pulsing the propellant flow rate and observing the change in decrement rates of the resultant chamber pressure oscillations. Although the inductive venturi and distributed capacitance core were found to have an appreciable stabilizing effect, the greatest stabilizing effect was achieved by using a more reactive fuel. Analyses of the chamber pressure oscillations indicated the presence of several predominant frequencies. (9 *refs.*)

(212) **Stabilization of low-frequency oscillations of liquid propellant rockets with fuel line stabilizer.** Y. T. Li. *Jet Propulsion*, **26**, 26–33, 39 (*Jan.*, 1956). Two basic types of stabilizer that can modify the dynamic characteristics of the fuel supply system sufficiently to give a stabilization effect (with respect to chugging oscillations) without the need of high supply pressure are described. The various dynamic and static characteristics of these stabilizers are analysed and the design problems discussed. (11 *refs.*)

(213) **Perturbation analysis of low-frequency rocket engine system dynamics on an analog computer.** B. N. Smith. *Jet Propulsion*, **26**, 40–45 (*Jan.*, 1956). Perturbation equations and computer circuit are developed for a pump-fed bipropellant system with turbine throttle valve area as the input variable. The frequency response of a typical system and the use of the computer model for estimating the effects of variations in the dimensions of interacting components on the frequency response are discussed. (8 *refs.*)

(214) **Ion rocket for space exploration proposed at Rocket Society meet.** *Aviation Wk.*, **66** (14), 27–30 (*April* 8, 1957). Reviews of papers on ion propulsion, rocket sleds and Vanguard, presented at A.R.S. Spring Meeting. Willinski and Orr propose a 3,300 lb. vehicle, designated Snooper, for solar system exploration. Ion propulsion system utilises nuclear-generated electricity and payload is 1,500 lb. Rocket sleds described are Snort and Smart propelled by liquid propellant rockets. Some details of the Vanguard sphere and the vehicle control jets are given.

ROCKET PROPELLANTS

(215) **Reactions between liquid fuels and oxidants.** M. Kilpatrick, A. G. Keenan, L. Baker and A. Palm. *Illinois Institute of Technology, Dept. of Chemistry*, 19 pp. (*June*, 1955.)

(216) **Liquid rocket propellants: fuels and oxidizers of the future.** R. A. Carpenter. *Industr. Engng. Chem.*, **49** (4), 42A–48A (*April*, 1957). General review of conventional chemical propellants, free radicals and working fluids for nuclear rockets.

INTERPLANETARY FILM STRIP

The Society has prepared, for the benefit of lecturers, a 35 mm. film strip containing 50 pictures showing modern rockets, orbital satellites, spacesuits, spaceship designs, and astronomical subjects. This strip will be invaluable not only to speakers wishing to address organisations of any type, but also to those wishing to have a private collection of rocket and space-flight pictures. If a projector is not available, the strip can of course be examined by one of the 35 mm. transparency viewers obtainable at any photographer's.

The cost is 10/- per strip, post free, which works out at the modest sum of 2½d. a picture. Orders should be sent to the Secretary at 12, Bessborough Gardens, S.W.1.

REVIEWS

A Technical Dictionary of Rockets and Astronautics

(By G. Partel. 108 pp. 1955. Associazione Italiana Razzi, Rome. 1000 lire or 14s.)

This dictionary gives the equivalents of 1,387 words and short phrases commonly met in literature dealing with rockets and astronautics in Italian, German, English and French. In compiling such a work it is difficult to know from how wide a field expressions should be gathered. A list containing only terms exclusive to rockets and astronautics would be very short and of little practical use. On the other hand it would be all too easy to allow the work to grow into a comprehensive technical dictionary. The author has produced a nicely-balanced work and one which should be of great use to the student of astronautics. The manuscript was checked by the various national astronautical societies and, as a result, the terminology is, in most cases, correct and there are none of the oddities found in most multi-lingual dictionaries. It is to be hoped that the few slightly unusual expressions ("brimstone" instead of "sulphur" is the worst found by the reviewer) will be corrected in the second edition.

J. HUMPHRIES.

"Gaseous Nebulae"

(By L. H. Aller. 362 pp., with many figures and plates. 1956. Chapman and Hall, Limited, London, 63s.)

This book is volume III in the International Astrophysics Series being published under the Editorships of Dr. M. A. Ellison and Professor A. C. B. Lovell. The aim of this series is to provide a collection of authoritative volumes dealing with the main branches of Astrophysics and Radio Astronomy, both of these sciences having expanded widely during recent years. The present volume fulfils its purpose admirably and should remain an invaluable source-book and teacher for both specialists and students for many years to come.

The author, Professor of Astronomy in the University of Michigan, has gathered together the extensive material both theoretical and practical on gaseous nebulae which has previously been scattered in various research journals on both sides of the Atlantic.

After an introductory chapter on the types of gaseous nebulae, he deals fully with the various methods of observation of these objects, describing the types of apparatus used. His third chapter deals with the distances, dimensions and spectra of the gaseous nebulae, distinguishing between the planetary, gaseous diffuse and galactic nebulae. This chapter itself ends with 156 references!

Chapter four contains a theoretical analysis of physical processes in gaseous nebulae and in chapter five the quantum mechanical treatment of forbidden line radiation is given.

The gaseous nebulae derive their energy from stars near or within them and chapter six gives an account of these stars, their magnitudes, luminosities and their spectra.

In chapter seven, Professor Aller considers the structure and internal motions of the planetary nebulae while in chapter eight some of the characteristics of the diffuse galactic nebulae are discussed in detail.

The book is well-written and the subject-matter presented clearly. There is an index, by name and subject, the illustrations are good and the many plates enhance the value of the book. Both the theoretical work and the quantitative aspects of observational work in this important branch of astrophysics are well-represented. Much of the discussion is based on plates taken with the 200-inch Hale telescope and the Michigan Schmidt camera. The massive lists of references at the ends of chapters are themselves an important feature of the work.

This book can not be called "popular," since the reader must possess a sound knowledge of mathematics, physics and astronomy to derive much benefit from it but to those so equipped it will be of immense value.

A. E. Roy.

ERRATUM

Theory of Combustion Instability in Liquid-Propellant Rocket Motors

The authors of the above book, reviewed in *J.B.I.S.*, 1957, **16** (2), 131, should have been given as Luigi Crocco and Sin-I Cheng.

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